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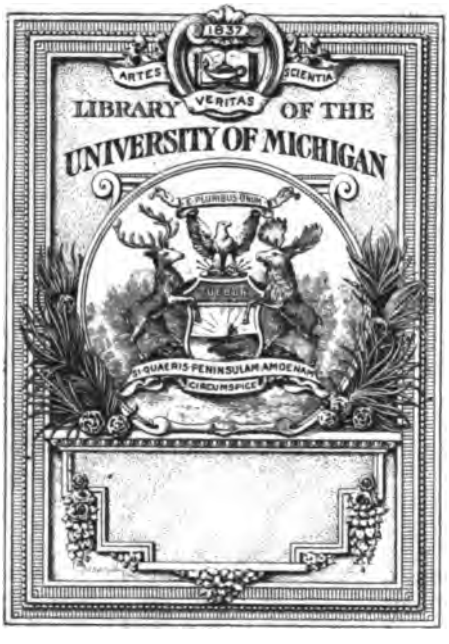
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# PROCEEDINGS

OF

# THE AMERICAN ASSOCIATION

FOR THE

# ADVANCEMENT OF SCIENCE,

THIRTY-THIRD MEETING,

HELD AT

## PHILADELPHIA, PENN.

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$$a = a_0 + \frac{da}{d\tau}\tau + \frac{1}{2}\frac{d^2a}{d\tau^2}\tau^2 + \frac{1}{2}\cdot\frac{1}{3}\frac{d^3a}{d\tau^3}\tau^3 + etc.$$

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Mr. John R. Baker, Rev. Dr. Geo. D. Boardman, Mr. Francis A. Cunningham, Col. Frank M. Etting, Mr. M. P. Handy, Mr. W. W. Harding, Hon. J. I. Clark Hare, Prof. Angelo Heilprin, Mr. Rudolph Hering, Mr. Thos. Hockley, Mr. J. B. Lippincott, Prof. Thos. Meehan, Dr. Edw. J. Nolan, Mr. Jos. Pennell, Mr. C. P Perot, Mr. Henry Phillips, Jr., Mr. Lloyd P. Smith, Mr. Frederick D. Stone, Mr. J. C. Strawbridge, Hon. A. W. Tourgee, Dr. Wm. H. Wahl, Hon. John Welsh, Mr. F. H. Williams.

## COMMITTEE ON MAILS, TELEGRAMS AND EXPRESS.

*Chairman*.—GEN. H. S. HUIDEKOPER.
*Secretary*.—MR. CHAS. A. ASHBURNER.

John S. Alexander, Chas. A. Ashburner, Dr. A. E. Foote, Mr. J. E. Farnum, Prof. A. H. Fetterolf, Prof. Edwin J. Houston, Gen. H. S. Huidekoper, Prof. C. N. Pierce, Mr. Franklin Platt, Dr. Carl Seiler, Mr. Jos. B. Townsend, Mr. W. H. Walmsley, Mr. Edw. H. Wood.

# SPECIAL COMMITTEES OF THE ASSOCIATION.

1. *Permanent Committee on Weights, Measures and Coinage.*

F. A. P. BARNARD of New York,
B. A. GOULD of Cambridge,
J. E. HILGARD of Washington,
H. A. NEWTON of New Haven,
E. B. ELLIOTT of Washington,
JOHN TROWBRIDGE of Cambridge,
A. M. MAYER of Hoboken.

2. *Committee on Membership.*

THE MEMBERS OF THE STANDING COMMITTEE.

3. *Committee on the best methods of Science-Teaching in the Public Schools.*

JOHN EATON of Washington,
R. H. THURSTON of Hoboken,
JAMES MAC ALISTER of Philadelphia,
J. BURKITT WEBB of Ithaca,
C. M. WOODWARD of St. Louis,
C. E. BESSEY of Ames.

This committee has power to add to its number.

4. *Committee on the Registration of Deaths, Births, and Marriages.*

E. B. ELLIOTT of Washington,
J. B. KILLEBREW of Nashville,
E. T. COX of San Francisco,
JOHN COLLETT of Indianapolis.

5. *Committee on Stellar Magnitudes.*

E. C. PICKERING of Cambridge,
LEWIS BOSS of Albany,
S. W. BURNHAM of Chicago,
ASAPH HALL of Washington,
WILLIAM HARKNESS of Washington,
E. S. HOLDEN of Madison,
SIMON NEWCOMB of Washington,
C. H. F. PETERS of Clinton,
ORMOND STONE of Univ. of Va.,
C. A. YOUNG of Princeton.

6. *Committee to confer with Committees of Foreign Associations for the Advancement of Science with reference to an International Convention of Scientific Associations.*

SIMON NEWCOMB of Washington,
T. STERRY HUNT of Montreal,
G. F. BARKER of Philadelphia,
J. W. POWELL of Washington,
E. C. PICKERING of Cambridge,
IRA REMSEN of Baltimore,
C. S. MINOT of Boston.

7. *Committee on Indexing the Literature of the Chemical Elements.*

H. CARRINGTON BOLTON of Hartford,
IRA REMSEN of Baltimore,
F. W. CLARK of Washington,
A. R. LEEDS of Hoboken,
A. A. JULIEN of New York.

8. *Committee on International Congress of Geologists.*

JAMES HALL of Albany,
J. W. DAWSON of Montreal,
J. S. NEWBERRY of New York,
T. STERRY HUNT of Montreal,
C. H. HITCHCOCK of Hanover,
RAPHAEL PUMPELLY of Newport,
J. P. LESLEY of Philadelphia,
J. W. POWELL of Washington,
G. A. COOK of New Brunswick,
JOHN STEVENSON of New York,
E. D. COPE of Philadelphia,
E. A. SMITH of Tuscaloosa.

9. *Committee to confer with the United States Geologist in regard to coöperation between the Government and State Geological Surveys.*

JAMES HALL of Albany,
T. STERRY HUNT of Montreal,
J. S. NEWBERRY of New York,
N. H. WINCHELL of Minneapolis,
C. H. HITCHCOCK of Hanover,
J. P. LESLEY of Philadelphia,
G. H. COOK of Brunswick,
E. A. SMITH of Tuscaloosa,
JOSEPH LE CONTE of San Francisco.

This Committee has power to add to its number.

10. *Committee on Interchange of Courtesies between the American and British Associations for the Advancement of Science.*

C. A. YOUNG of Princeton,
J. P. LESLEY of Philadelphia,
J. W. DAWSON of Montreal,
T. STERRY HUNT of Montreal,
E. S. MORSE of Salem,
T. C. MENDENHALL of Washington.
F. W. PUTNAM of Cambridge.

11. *Committee in relation to Duty on Scientific Books.*

H. A. ROWLAND of Baltimore,
C. A. YOUNG of Princeton,
J. W. POWELL of Washington,
J. D. COX of Cincinnati,
E. S. MORSE of Salem.

12. *Committee on Uniformity of Graphic Illustrations in representing facts in Statistics, etc.*

E. B. ELLIOTT of Washington,
J. E. HILGARD of Washington,
CHARLES WARREN of Washington,
WILLIAM KENT of Pittsburgh.

13. *Committee on the Investigation of Fermentation and its Effects.*

ALFRED SPRINGER of Cincinnati,
F. W. CLARKE of Washington,
G. M. STERNBERG of Washington,
H. W. WILEY of Washington,
CLIFFORD RICHARDSON of Washington.

14. *Committee on Anatomical Nomenclature, with Special reference to the Brain.*

JOSEPH LEIDY of Philadelphia,
HARRISON ALLEN of Philadelphia,
H. OSBORN of Princeton,
T. B. STOWELL of Cortland,
B. G. WILDER of Ithaca.

15. *Committee on the Encouragement of Researches upon the Health and Disease of Plants.*

J. C. ARTHUR of Charles City,
W. J. BEAL of Agricultural College, Mich.
C. E. BESSEY of Ames,
T. J. BURRILL of Champaign,
W. G. FARLOW of Cambridge,
C. H. PECK of Albany,
J. T. ROTHROCK of West Chester.

16. *Committee on Physics Teaching.*

T. C. MENDENHALL of Washington,
W. A. ANTHONY of Ithaca,
H. S. CARHART of Evanston,
F. H. SMITH of Charlottesville,
JOHN TROWBRIDGE of Cambridge.

17. *Committee to present to the Postmaster General the importance of a change in the postal laws in relation to the transportation of Botanical specimens through the mails.*

L. F. WARD of Washington,
GEORGE VASSEY of Washington,
J. W. CHICKERING, JR., of Washington.

18. *Auditors.*

HENRY WHEATLAND of Salem,
THOMAS MEEHAN of Germantown.

## MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION OF GEOLOGISTS AND NATURALISTS.

| MEETING. | DATE. | PLACE. | CHAIRMAN. | SECRETARY. | ASSIS'T SEC'Y. | TREASURER. |
|---|---|---|---|---|---|---|
| 1st | April 2, 1840, | Philadelphia, | Edward Hitchcock,* | L. C. Beck,* | | |
| 2d | April 5, 1841, | Philadelphia, | Benjamin Silliman,* | L. C. Beck,* | B. Silliman, jr.,*<br>C. B. Trego, | |
| 3d | April 25, 1842, | Boston, | S. G. Morton,* | C. T. Jackson,* | J. D. Whitney,<br>M. B. Williams, | |
| 4th | April 26, 1843, | Albany, | Henry D. Rogers,* | B. Silliman, jr.,* | | John Locke.* |
| 5th | May 8, 1844, | Washington, | John Locke,* | B. Silliman, jr.,*<br>O. P. Hubbard, | | Douglas Houghton.* |
| 6th | April 30, 1845, | New Haven, | Wm. B. Rogers,* | B. Silliman, jr.,*<br>J. Lawrence Smith,* | | Douglas Houghton.* |
| 7th | Sept. 2, 1846, | New York, | C. T. Jackson,* | B. Silliman, jr.,* | | E. C. Herrick.* |
| 8th | Sept. 20, 1847, | Boston, | Wm. B. Rogers,†* | Jeffries Wyman,* | | B. Silliman, jr.* |

* Deceased.

† Professor ROGERS, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

## MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

| MEETING. | DATE. | PLACE. | PRESIDENT. | VICE-PRESIDENT. | GENERAL SECRETARY. | PERMANENT SEC'Y. | TREASURER. |
|---|---|---|---|---|---|---|---|
| 1st | Sept. 20, 1848, | Philadelphia, Pa., | W. C. Redfield,* | | Walter R. Johnson,* | | Jeffries Wyman.* |
| 2d | Aug. 14, 1849, | Cambridge, Mass., | Joseph Henry,* | | E. N. Horsford, 1 | | A. L. Elwyn.* |
| 3d | Mar. 12, 1850, | Charleston, S. C., | A. D. Bache,* 2 | | L. R. Gibbs, 3 | | St. J. Ravenel.* 4 |
| 4th | Aug. 19, 1850, | New Haven, Conn., | A. D. Bache,* | | E. C. Herrick,* | | A. L. Elwyn.* |
| 5th | May 5, 1851, | Cincinnati, Ohio, | A. D. Bache,* | | W. B. Rogers, 5* | S. F. Baird, | S. F. Baird. 6 |
| 6th | Aug. 19, 1851, | Albany, N. Y., | Louis Agassiz,* | | W. B. Rogers, | S. F. Baird, | A. L. Elwyn.* |
| 7th | July 28, 1853, | Cleveland, Ohio, | Benjamin Pierce, | | S. St. John, 7 | S. F. Baird, | A. L. Elwyn.* |
| 8th | April 26, 1854, | Washington, D. C., | J. D. Dana, | | J. Lawrence Smith,* | Joseph Lovering, | J. L. LeConte* 8 |
| 9th | Aug. 15, 1855, | Providence, R. I., | John Torrey,* | | Wolcott Gibbs, | Joseph Lovering, | A. L. Elwyn.* |
| 10th | Aug. 20, 1856, | Albany, N. Y., | James Hall, | | B. A. Gould, | Joseph Lovering, | A. L. Elwyn.* |
| 11th | Aug. 12, 1857, | Montreal, Canada, | Alexis Caswell,* 9 | Alexis Caswell,* | John L. LeConte,* | Joseph Lovering, | A. L. Elwyn.* |
| 12th | April 28, 1858, | Baltimore, Md., | Alexis Caswell,* 10 | John E. Holbrook,*† | W. M. Gillespie,* 11 | Joseph Lovering, | A. L. Elwyn.* |
| 13th | Aug. 3, 1859, | Springfield, Mass., | Stephen Alexander,* | Edward Hitchcock,* | William Chauvenet,* | Joseph Lovering, | A. L. Elwyn.* |
| 14th | Aug. 1, 1860, | Newport, R. I., | Isaac Lea, | B. A. Gould, | Joseph LeConte, | Joseph Lovering, | A. L. Elwyn.* |
| 15th | Aug. 15, 1866, | Buffalo, N. Y., | F. A. P. Barnard, | A. A. Gould,* 12 | Elias Loomis, 13 | Joseph Lovering, | A. L. Elwyn.†* |
| 16th | Aug. 21, 1867, | Burlington, Vt., | J. S. Newberry, | Wolcott Gibbs, | C. S. Lyman, | Joseph Lovering, | A. L. Elwyn.†* |
| 17th | Aug. 5, 1868, | Chicago, Ill., | B. A. Gould, | Charles Whittlesey, | Simon Newcomb, 14 | Joseph Lovering, | A. L. Elwyn.†* |
| 18th | Aug. 18, 1869, | Salem, Mass., | J. W. Foster,* | O. N. Rood, | O. C. Marsh, | F. W. Putnam, 15 | A. L. Elwyn.†* |
| 19th | Aug. 17, 1870, | Troy, N. Y., | T. S. Hunt, 16 | T. S. Hunt, | F. W. Putnam, 17 | Joseph Lovering, | A. L. Elwyn.†* |
| 20th | Aug. 16, 1871, | Indianapolis, Ind., | Asa Gray, | G. F. Barker, | F. W. Putnam, | Joseph Lovering, | W. S. Vaux.* |
| 21st | Aug. 15, 1872, | Dubuque, Iowa, | J. Lawrence Smith,* | Alex. Winchell, | E. S. Morse, | Joseph Lovering, | W. S. Vaux.* |
| 22d | Aug. 20, 1873, | Portland, Me., | Joseph Lovering, | A. H. Worthen,† | C. A. White, | F. W. Putnam, | W. S. Vaux.* |
| 23d | Aug. 12, 1874, | Hartford, Conn., | J. L. LeConte,* | C. S. Lyman, | A. C. Hamlin, | F. W. Putnam, | W. S. Vaux.†* |

1. In place of Jeffries Wyman, *not present.*
2. In place of Joseph Henry, *not present.*
3. In place of E. C. Herrick, *not present.*
4. In place of A. L. Elwyn, *not present.*
5. In place of E. C. Herrick, *not present.*
6. In place of A. L. Elwyn, *not present.*
7. In place of J. D. Dana, *not present.*
8. In place of A. L. Elwyn, *not present.*
9. In place of J. W. Bailey, *deceased.*
10. In place of Jeffries Wyman, *not present.*
11. In place of Wm. Chauvenet, *not present.*
12. In place of R. W. Gibbes, *not present.*
13. In place of W. P. Trowbridge, *not present.*
14. In place of A. P. Rockwell, *called home 1st day.*
15. In place of Joseph Lovering, *in Europe.*
16. In place of Wm. Chauvenet, *too ill to be present.*
17. In place of C. F. Hartt, *in Brazil.*

* Deceased. † Not present at the meeting.

## MEETINGS AND OFFICERS OF THE ASSOCIATION Continued.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

[illegible] In the absence of [illegible]
[illegible] In the absence of [illegible]
[illegible] In the absence of A. M. Mayer.
[illegible] In the absence of John Trowbridge.
[illegible] Deceased.

[illegible] The Subsection united with Sec. B.
[illegible] In the absence of George Little.
[illegible] In the absence of George Engelmann.
[illegible] In the absence of S. P. Sharples.
† Not present

[illegible] In the absence of G. S. Blackie.
[illegible] In the absence of A. C. Wetherby.
[illegible] In the absence of W. R. Nichols.
[illegible] In place of H. W. Wiley, called away.

## MEETINGS AND OFFICERS OF THE ASSOCIATION. (*Continued.*)

| MEETING. | DATE. | PLACE. | PRESIDENT. | VICE PRESIDENTS. | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Section A. | Section B. | Section C. | Section D. | Section E. |
| 31st | Aug. 23, 1882. | Montreal, Can. | J. W. Dawson, | W. A. Rogers,[1] | T.C. Mendenhall, | H. C. Bolton, | W. P.Trowbridge, | E. T. Cox, |
| 32nd | Aug. 15, 1883. | Minneapolis, M. | C. A. Young, | W. A. Rogers, | H. A. Rowland, | E. W. Morley, | De Volsen Wood,[7] | C.H. Hitchcock, |
| 33rd | Sept. 3, 1884. | Philadelphia, Pa. | J. P. Lesley, | H. T. Eddy, | J. Trowbridge, | J. W. Langley, | R. H. Thurston, | N. H. Winchell, |

| VICE PRESIDENTS. | | | | Permanent Secretary. | General Secretary. | Assistant Gen. Secretary. | SECRETARIES OF SECTIONS. | |
|---|---|---|---|---|---|---|---|---|
| Section F. | Section G. | Section H. | Section I. | | | | Section A. | Section B. |
| W. H. Dall, | A. H. Tuttle, | Alex. Winchell,[2] | E. B. Elliott, | F. W. Putnam, | Wm. Saunders, | J. R. Eastman, | H. T. Eddy, | C. S. Hastings, |
| W. J. Beal, | J. D. Cox, | O. T. Mason, | F. B. Hough, | F. W. Putnam, | J. R. Eastman, | Alfred Springer, | G. W. Hough,[8] | F. E. Nipher,[9] |
| E. D. Cope, | T. G.Wormley, | E. S. Morse, | John Eaton, | F. W. Putnam, | Alfred Springer, | C. S. Minot,[12] | G. W. Hough, | N. D. C. Hodges, |

| SECRETARIES OF THE SECTIONS. | | | | | | | Treasurer. |
|---|---|---|---|---|---|---|---|
| Section C. | Section D. | Section E. | Section F. | Section G. | Section H. | Section I. | |
| Alfred Springer, | J. B. Webb,[3] | H. S. Williams,[4] | Wm. Osler,[5] | Robt. Brown, jr., | O. T. Mason, | F. B. Hough,[6*] | ———————* |
| J. W. Langley,[10] | J. B. Webb,[11] | A. A. Julien, | S. A. Forbes, | Carl Seiler, | G. H. Perkins, | Jos. Cummings, | William Lilly. |
| H. Carmichael,[13] | J. B. Webb, | E. A. Smith, | C. E. Bessey, | R. Hitchcock, | G. H. Perkins,[14] | C. W. Smiley, | William Lilly. |

1 In the absence of William Harkness.
2 In the absence of Daniel Wilson.
3 In the absence of C. B. Dudley.
4 In the absence of C. E. Dutton.
5 In the absence of C. S. Minot.
6 F. B. Hough was called home and J. R. Dodge acted at the close of the meeting.
7 Absent but place was not filled.
8 In the absence of W. W. Johnson.
9 In the absence of C. K. Wead.
*Deceased.
10 W. M. McMurtrie, last three days of meeting.
11 Pro tempore.
12 In the absence of E. S. Holden.
13 In the absence of R. B. Warder.
14 In the absence of W. H. Holmes.

# COMMONWEALTH OF MASSACHUSETTS.

## IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND SEVENTY-FOUR.

# AN ACT

### To Incorporate the "American Association for the Advancement of Science."

*Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:*

Section 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding and conveying real and personal property, which it now is, or hereafter may be, possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

Section 2. Said corporation may have and hold by purchase, grant, gift or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

Section 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

Section 4. This act shall take effect upon its passage.

House of Representatives, March 10, 1874.
Passed to be enacted,
John E. Sanford, *Speaker.*

In Senate, March 17, 1874.
Passed to be enacted,
Geo. B. Loring, *President.*

March 19, 1874.
Approved,
W. B. Washburn.

Secretary's Department,
Boston, April 3, 1874.
A true copy. Attest:
David Pulsifer,
Deputy Secretary of the Commonwealth.

# CONSTITUTION

OF THE

# AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

**Incorporated by Act of the General Court of the Commonwealth of Massachusetts.**

---

## OBJECTS.

ARTICLE 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

## MEMBERS, FELLOWS, PATRONS AND HONORARY FELLOWS.

ART. 2. The Association shall consist of Members, Fellows, Patrons, and Honorary Fellows.

ART. 3. Any person may become a Member of the Association upon recommendation in writing by two members or fellows, nomination by the Standing Committee, and election by a majority of the members and fellows present in General Session.

ART. 4. Fellows shall be nominated by the Standing Committee from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of fellows shall be by ballot and a majority vote of the members and fellows present in General Session.

ART. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a Patron, and shall be entitled to all the privileges of a member and to all its publications.

ART. 6. Honorary Fellows of the Association, not exceeding three for each section, may be elected; the nominations to be made by the Standing Committee and approved by ballot in the respective sections before election by ballot in General Session. Honorary Fellows shall be entitled to all the privileges of fellows and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been reëlected. The Standing Committee shall have power to exclude from the Association any member or fellow, on satisfactory evidence that said member or fellow is an improper person to be connected with the Association, or has in the estimation of the Committee made improper use of his membership or fellowship.

ART. 8. No member or fellow shall take part in the organization of, or hold office in, more than one section at any one meeting.

## OFFICERS.

ART. 9. The Officers of the Association shall be elected by ballot in General Session from the fellows, and shall consist of a President, a Vice President from each section, a Permanent Secretary, a General Secretary, an Assistant General Secretary, a Treasurer, and a Secretary of each Section; these, with the exception of the Permanent Secretary, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be reëligible for the next two meetings. The term of office of Permanent Secretary shall be five years.

ART. 10. The President, or, in his absence, the senior Vice President present, shall preside at all General Sessions of the Association and at all meetings of the Standing Committee. It shall also be the duty of the President to give an address at a General Session of the Association at the meeting following that over which he presided.

ART. 11. The Vice Presidents shall be the chairmen of their respective Sections, and of their Sectional Committees, and it shall be part of their duty to give an address, each before his own section, at such time as the Standing Committee shall determine. The Vice Presidents may appoint temporary chairmen to preside over the sessions of their sections, but shall not delegate their other duties. The Vice Presidents shall have seniority in order of their continuous membership in the Association.

ART. 12. The General Secretary shall be the Secretary of all General Sessions of the Association, and shall keep a record of the business of these sessions. He shall receive the records from the Secretaries of the

Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting. He shall receive proposals for membership and bring them before the Standing Committee.

ART. 13. The Assistant General Secretary shall be the Secretary of the Standing Committee. He shall give to the Secretary of each Section the titles of papers assigned to it by the Standing Committee.

ART. 14. The Permanent Secretary shall be the executive officer of the Association under the direction of the Standing Committee. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually a general report for publication in the annual volume of Proceedings. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least three months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Standing Committee, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Standing Committee, and shall pay over to the Treasurer such unexpended funds as the Standing Committee may direct. He shall receive and hold in trust for the Association all books, pamphlets and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Standing Committee. He shall receive all communications addressed to the Association during the interval between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Standing Committee, and may employ one or more clerks at such compensation as may be agreed upon by the Standing Committee.

ART. 15. The Treasurer shall invest the funds received by him in such securities as may be directed by the Standing Committee. He shall annually present to the Standing Committee an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Standing Committee, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Standing Committee.

ART. 16. The Secretaries of the Sections shall keep the records of their respective sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the Secretaries of the Sectional Committees. The Secretaries shall have seniority in order of their continuous membership in the Association.

ART. 17. In case of a vacancy in the office of the President, one of the Vice Presidents shall be elected by the Standing Committee as the President of the meeting. Vacancies in the offices of Vice President, Permanent Secretary, General Secretary, Assistant General Secretary, and Treasurer, shall be filled by nomination of the Standing Committee and election by ballot in General Session. A vacancy in the office of Secretary of a Section shall be filled by nomination and election by ballot in the Section.

ART. 18. The Standing Committee shall consist of the past Presidents, and the Vice Presidents of the last meeting, together with the President, the Vice Presidents, the Permanent Secretary, the General Secretary, the Assistant General Secretary, the Secretaries of the Sections, and the Treasurer of the current meeting, with the addition of one fellow elected from each Section by ballot on the first day of its meeting. The members present at any regularly called meeting of the Committee, provided there are at least five, shall form a quorum for the transaction of business. The Standing Committee shall meet on the day preceding each annual meeting of the Association, and arrange the programme for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Committee shall be held in the committee room at 9 o'clock, A. M., on each day of the meeting of the Association. Special meetings of the Committee may be called at any time by the President. The Standing Committee shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Committee. The Committee shall receive and assign papers to the respective sections; examine and, if necessary, exclude papers; decide which papers, discussions and other

proceedings shall be published, and have the general direction of the publications of the Association; manage the financial affairs of the Association; arrange the business and programmes for General Sessions; suggest subjects for discussion, investigation or reports; nominate members and fellows; and receive and act upon all invitations extended to the Association and report the same at a General Session of the Association.

ART. 19. The Nominating Committee shall consist of the Standing Committee, and one member or fellow elected by each of the Sections. It shall be the duty of this Committee to meet at the call of the President and nominate the general officers for the following meeting of the Association. It shall also be the duty of this Committee to recommend the time and place for the next meeting. The Vice President and Secretary of each Section shall be recommended to the Nominating Committee by a sub-committee consisting of the Vice President, Secretary, and three members or fellows elected by the Section.

### MEETINGS.

ART. 20. The Association shall hold a public meeting annually, for one week or longer, at such time and place as may be determined by vote of the Association, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Standing Committee may designate.

ART. 21. General Sessions shall be held at 10 o'clock, A. M., unless otherwise ordered, on every day of the meeting, Sunday excepted, and at such other times as may be appointed by the Standing Committee.

### SECTIONS AND SUBSECTIONS.

ART. 22. The Association shall be divided into nine Sections, namely :— A, *Mathematics and Astronomy;* B, *Physics;* C, *Chemistry, including its application to agriculture and the arts;* D, *Mechanical Science;* E, *Geology and Geography;* F, *Biology;* G, *Histology and Microscopy;* H, *Anthropology;* I, *Economic Science and Statistics.* The Standing Committee shall have power to consolidate any two or more Sections temporarily, and such consolidated Sections shall be presided over by the senior Vice President and Secretary of the Sections comprising it.

ART. 23. Immediately on the organization of a Section there shall be three fellows elected by ballot after open nomination, who, with the Vice President and Secretary, shall form its Sectional Committee. The Sectional Committees shall have power to fill vacancies in their own numbers. Meetings of the Sections shall not be held at the same time with a General Session.

ART. 24. The Sectional Committee of any Section may at its pleasure form one or more temporary Subsections, and may designate the officers thereof. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section.

ART. 25. A paper shall not be read in any Section nor Subsection until it has been received from the Standing Committee and placed on the programme of the day by the Sectional Committee.

### SECTIONAL COMMITTEES.

ART. 26. The Sectional Committees shall arrange and direct the business of their respective Sections. They shall prepare the daily programmes and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programmes except such as have passed the Standing Committee. No change shall be made in the programme for the day in a Section without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the programme; but every such title, with the abstract of the paper or the paper itself, must be returned to the Standing Committee with the reasons why it was refused.

ART. 27. The Sectional Committees shall examine all papers and abstracts referred to the sections, and they shall not place on the programme any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

### PAPERS AND COMMUNICATIONS.

ART. 28. All members and fellows must forward to the Permanent Secretary, as early as possible, and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be referred by the Standing Committee to the Sectional Committee until an abstract of the paper or the paper itself has been received.

ART. 29. If the author of any paper be not ready at the time assigned, the title may be dropped to the bottom of the list.

ART. 30. Whenever practicable, the proceedings and discussions at General Sessions, Sections and Subsections shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the Secretaries.

### Printed Proceedings.

ART. 31. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers or abstracts ready for the press and forward them to the Permanent Secretary within this interval, otherwise only the abstracts or titles taken from the "title blanks" will appear in the printed volume. The Standing Committee shall have power to order the printing of any paper by abstract or title only. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Standing Committee. Immediately on publication of the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Standing Committee. The Standing Committee shall also designate the institutions to which copies shall be distributed.

### Local Committee.

ART. 32. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

### Library of the Association.

ART. 33. All books and pamphlets received by the Association shall be in the charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full shall be allowed to call for books and pamphlets, which shall be delivered to them at their expense, on their giving a receipt agreeing to make good any loss or damage and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets in circulation must be returned at each meeting. Not more than five books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Standing Committee.

### Admission Fee and Assessments.

ART. 34. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

ART. 35. The annual assessment for members and fellows shall be three dollars.

ART. 36. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall become a Life Member and as such shall be exempt from all further assessments, and shall be entitled to the Proceedings of the Association. All money thus received shall be invested as a permanent fund, the income of which shall be used only to assist in original research, unless otherwise directed by unanimous vote of the Standing Committee.

ART. 37. All admission fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

### Accounts.

ART. 38. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually, by Auditors appointed by the Standing Committee.

### Alterations of the Constitution.

ART. 39. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in General Session, after notice given at a General Session of a preceding meeting of the Association.

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## ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

1. The retiring President introduces the President elect, who takes the chair.
2. Formalities of welcome of the Association as may be arranged by the Local Committee.
3. Report of the list of papers entered and their reference to the Sections.
4. Other reports.
5. Announcements of arrangements by the Local Committee.
6. Election of members.
7. Election of fellows.
8. Unenumerated business.
9. Adjournment to meet in Sections.

This order, so far as applicable, to be followed in subsequent General Sessions.

# MEMBERS

OF THE

# AMERICAN ASSOCIATION.

FOR THE

## ADVANCEMENT OF SCIENCE.[1]

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### PATRON.[2]

THOMPSON, MRS. ELIZABETH, Stamford, Conn. (22).
LILLY, GEN. WILLIAM, Mauch Chunk, Carbon Co., Pa. (28).
HERRMAN, MRS. ESTHER, 59 West 56th St., New York, N. Y. (29).

### MEMBERS.[3]

Aaron, Eugene M., P. O. Box 916, Philadelphia, Pa. (33).
Abbot, Griffith Evans, M.D., Falls of Schuylkill, Philadelphia, Pa. (33).
Abbott, Helen C. DeS., 1509 Locust St., Philadelphia, Pa. (33).
Abert, Col. James W., Newport, Ky. (31).
Abert, S. Thayer, 1907 Pennsylvania Avenue, Washington, D. C. (30).
Adams, Frank, 41 McGill College Avenue, Montreal, Can. (29).
Adams, John S., M. D., Oakland, Cal. (29).
Adams, Capt. Robert C., Montreal, Can. (31).
Agard, Dr. A. H., 1259 Alice St., Oakland, Alameda Co., Cal. (28).
Agnew, Dr. Cornelius R., 266 Madison Ave., New York, N. Y. (32).

[1] The numbers in parentheses indicate the meeting at which the member was elected. The Constitution requires that the names of all members two or more years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the annual volume of Proceedings bound in paper. *The payment of ten dollars at one time entitles a member to the subsequent volumes bound in cloth, or by the payment of twenty dollars, to the volumes bound in half morocco.*

[2] Persons contributing one thousand dollars or more to the Association are classed as Patrons, and are entitled to the privileges of members and to the publications.

The names of Patrons are to remain permanently on the list.

[3] Any Member or Fellow may become a Life Member by the payment of fifty dollars. The money derived from Life Memberships is invested as a fund, the income of which is to be used only to aid in original research. Life Members are exempt from the annual assessment, and are entitled to the annual volume. The names of Life Members are printed in small capitals in the regular list of Members and Fellows.

Aher, Mrs. Mary R. Alling, care Rev. H. Alling, South Cairo, Greene Co., N. Y. (29).
Ainslie, Charles N., Rochester, Minn. (32).
Alden, Prof. Geo. I., Worcester, Mass. (33).
Alexander, Miss Jane, Jamaica Plain, Mass. (33).
Allderdice, Wm. H., U. S. Navy, care Navy Dep't, Washington, D. C. (33).
Allen, Edmund T., 404 Market St., St. Louis, Mo. (27).
Allen, J. M., Hartford, Conn. (22).
Allen, Jno. R., Linwood, Del. Co., Pa. (33).
Alling, J. C., Hasbrouck Institute, 109 Grand St., Jersey City, N. J. (31).
Allison, Henry, Fort Worth, Texas (32).
Alvord, Benj., Lieut. U. S. A., Fort Hays, Kan. (33).
Anderson, Newton M., Columbus, Ohio (30).
Andrews, L. W., Ph. D., Springfield, Mass. (31).
Ansley, Clark F., Swedona, Mercer Co., Ill. (32).
Antisell, Thomas, M.D., 1311 Q St., Washington, D. C. (33).
Appleton, Rev. Edw. W., D.D., Ashbourne P. O., Montgomery Co., Pa. (28).
Apthorp, Henry, Ashtabula, Ohio (32).
Archambault, U. E., P. O. Box 1944, Montreal, Can. (31).
Armstrong, Lucius H., St. Nicholas, Duval Co., Fla. (30).
Armstrong, Mrs. Lucius H., St. Nicholas, Duval Co., Fla. (30).
Arnold, Lauren B., Rochester, N. Y. (30).
Atkinson, Jno. B., Earlington, Hopkins Co., Ky. (26).
Atwater, Richard M., Millville, N. J. (29).
Atwood, E. S., East Orange, N. J. (29).
Atwood, Oscar, Rutland, Vt. (31).
Auchincloss, Wm. S., 209 Church St., Philadelphia, Pa. (29).
Aughey, Prof. Samuel, Univ. of Nebraska, Lincoln, Neb. (29).
Austin, Miss Mary, Mattapan Station, Milton, Mass. (31).
Avila, A. F. de, Ithaca, N. Y. (33).
Ayres, Prof. Brown, Tulane University, New Orleans, La. (31).
Ayres, Dr. S. C., 64 W. 7th St., Cincinnati, Ohio (30).

Babbit, John, Fredericton, N. B. (29). [(32).
Babbitt, Miss Franc E., P. O. Box 75, Little Falls, Morrison Co., Minn.
Babcock, Geo. H., 30 Cortlandt St., New York, N. Y. (33).
Babcock, S. Moulton, N. Y. Agric. Experiment Station, Geneva, N. Y. (33).
Bailey, E. H. S., Lawrence, Douglas Co., Kan. (25).
Baker, Frank, M. D., 326 C St., N. W., Washington, D. C. (31).
Baker, Prof. I. O., Illinois Industrial Univ., Champaign, Ill. (30).
Baker, Richard D., 1414 Arch St., Philadelphia, Pa. (33).
Baker, Prof. T. R., Millersville, Lancaster Co., Pa. (22).
Balderston, C. Canby, Westtown, Chester Co., Pa. (33).

Baldwin, Miss Mary A., Summer Ave., Cor. Kearney St., Newark, N. J. (31).
Baldwin, Very Rev. Dean Maurice S., Montreal, Can. (31).
Balen, Abraham D., Plainfield, N. J. (31).
Ballard, Harlan H., Lenox, Mass. (31).
Banes, Charles H., 2416 Spring Garden St., Philadelphia, Pa. (31).
Baptie, George, Normal School, Ottawa, Ontario, Can. (29).
Bardeen, Francis L., M. D., Washington College, Chestertown, Md. (32).
Barge, B. F., Mauch Chunk, Pa. (33).
Barker, Mrs. Martha M., care of H. R. Barker, 8 and 10 Central St., Lowell, Mass. (31).
Barnes, Charles J. (27).
Barnes, Prof. Chas. R., 297 Columbia St., Lafayette, Ind. (33).
Barns, Carl, Ph.D., National Museum, Washington, D. C. (33).
Bartlett, Dr. Homer L., Flatbush, L. I. (28).
Bartley, Elias H., M.D., 401 Pacific St., Brooklyn, N. Y. (33).
Bassett, Daniel A., Crawfordsville, Ind. (29).
Bassnett, Thomas, Box 936, Jacksonville, Fla. (8).
Bassnett, Mrs. Thomas, Box 936, Jacksonville, Fla. (24).
Bastian, Dr. David I., Clinton, Worcester Co., Mass. (25).
Bastin, Prof. E. S., Highland Park, Chicago, Ill. (29).
Batchelor, Charles, Electrician, Menlo Park, N. J. (28).
Bates, Henry Hobart, M.A., U. S. Patent Office, Washington, D. C. (33).
Batterson, J. G., Hartford, Conn. (23).
Battle, Herbert B., N. C. Agric. Experiment Station, Raleigh, N. C. (33).
Baylor, James B., U. S. C. and G. Survey Office, Washington, D. C. (33).
Bayne, Prof. Herbert A., Ph.D., Royal Military College, Kingston, Ont. (29).
Beach, Charles M., Merchant, Hartford, Conn. (23).
Beach, J. Watson, Merchant, Hartford, Conn. (23).
Beach, William H., Beloit, Wis. (21).
Beadle, Delos W., St. Catharines, Ontario, Can. (31).
Beall, Thomas, Lindsay, Ontario, Can. (31).
Bean, Thos. E., Box 441, Galena, Ill. (28).
Beard, Richard O., M. D., 1221 Nicollet Ave., Minneapolis, Minn. (32).
Beardsley, Prof. Arthur, Swarthmore College, Swarthmore, Del. Co., Pa. (33).
Beatty, Prof. James, Jr., 92 Dugan's Wharf, Baltimore, Md. (33).
Beaudry, J. Alphonse U., 97 St. James St., Montreal, Can. (31).
Beauregard, Gen. Gustave T., 359 St. Charles Ave., New Orleans, La. (30).
Bechdolt, Adolphus F., Mankato, Minn. (32).
Beckwith, Henry C., Passed Ass't Eng'r U. S. N., Coleman's Station, N. Y. (29).
Belknap, Chas., Lieut. U. S. N., U. S. S. Vandalia, care Navy Dept., Washington, D. C. (29).
Belknap, Morris B., Louisville, Ky. (29).

Belknap, Wm. B., Louisville, Ky. (29).
Bell, Alex. Melville, 1525 35th St., Washington, D. C. (31).
Bell, John J., Exeter, N. H. (22).
Bell, Thomas D., McGill College, Montreal, Can. (31).
Bemis, Hon. A. S., President of the Common Council, Buffalo, N. Y. (25).
Bemrose, Joseph, 158 P. O., Montreal, Can. (31).
Benjamin, E. B., 6 Barclay St., New York, N. Y. (19).
Benjamin, Marcus, 43 East 67th St., New York, N. Y. (27).
Bennett, Prof. Wm. Z., Wooster, Wayne Co., Ohio (33).
Berg, Walter G., Ass't Eng. Lehigh Valley R. R. Co., Mauch Chunk, Pa. (33).
Best, Wm. F., 74 Germain St., St. John, N. B. (29).
Beveridge, David, 250 Hennepin Ave., Minneapolis, Minn. (33).
Bickmore, Mrs. Albert S., 12 East 41st St., New York, N. Y. (31).
Biddle, Wm. F., 209 So. 3rd St., Philadelphia, Pa. (33).
Bierstadt, Albert, Brevoort House, New York, N. Y. (28).
Bigelow, A. T., D. D. S., Bismarck, Dakota (32).
Bigelow, Otis, 1501 18th St., N. W., Washington, D. C. (30).
Bigelow, Robert P., 1501 18th St., N. W., Washington, D. C. (32).
Bill, Charles, Springfield, Mass. (17).
Bingham, Mrs. Martha A., Kansas City, Mo. (32).
Birge, Charles P., Keokuk, Iowa (29).
Blackwell, Mrs. A. B., Elizabeth, N. J. (30).
Blaisdell, F. E., Poway, San Diego Co., Cal. (29).
Blake, Mrs. Clarence J., 19 St. James Avenue, Boston, Mass. (29).
Blake, Francis C., Mansfield Valley P. O., Allegheny Co., Pa. (29).
Blakslee, Prof. T. M., Hamilton, N. Y. (31).
Blankenburg, Rudolph, 1326 Arch St., Philadelphia, Pa. (33).
Blatchford, Eliphalet W., 375 La Salle Ave., Chicago, Ill. (17).
Blish, W. G., Niles, Mich. (33).
Blitz, Adolph, M.D., Minneapolis, Minn. (32).
Blodget, Lorin, 1329 So. Broad St., Philadelphia, Pa. (33).
Blount, Henry F., Evansville, Vanderburg Co., Ind. (32).
Boardman, Miss E. D., 120 Beacon St., Boston, Mass. (29).
Boardman, Mrs. Wm. D., 38 Kenilworth St., Roxbury, Mass. (28).
Bocage, Miss Annie, Pine Bluff, Ark. (33).
Boerner, Chas. G., Vevay, Ind. (29).
Boice, Miss Carrie A., Camden, N. J. (33).
Bolles, Prof. Albert S., Univ. of Pa., Philadelphia, Pa. (33).
Bond, Geo. M., The Pratt and Whitney Co., Hartford, Conn. (33).
Bond, Geo. W., Boston, Mass. (29).
Bourke, John G., Capt. 3rd Cavalry, U. S. A., care Adj. Gen. U. S. A., Washington, D. C. (33).
Bourland, Dr. Addison M., Van Buren, Ark. (29).
Bowers, Miss Virginia K., Appeal Office, Memphis, Tenn. (27).
Bowles, Francis T., 1823 Jefferson Place, Washington, D. C. (33).
Bowles, George J., 1466 St. Catherine St., Montreal, Can. (31).

Bowles, Miss Margaretta, The Institute, Columbia, Tenn. (26).
Bowman, Chas. G., Lieut. U. S. N., Naval Observ., Washington, D. C. (33).
Bowser, Mrs. Anna C., 328 Third St., Louisville, Ky. (33).
Boyd, William, Cambridge, Mass. (29).
Boyè, M. H., Coopersburg, Lehigh Co., Pa. (33).
Boynton, Miss S. P., Box 150, Lynn, Mass. (19).
Brackett, Solomon H., St. Johnsbury, Vt. (29).
Bradford, Edward H., M.D., 150 Boylston St., Boston, Mass. (29).
Bradford, Royal B., Lt. Comd'r, U. S. N., 21 Brinley St., Newport, R. I. (31).
Braid, Andrew, Coast and Geodetic Survey Office, Washington, D. C. (33).
Braid, James W., Nashville, Tenn. (33).
Brainerd, Thos. C., P. O. Box 720, Montreal, Can. (31).
Braley, Sam'l T., Rutland, Vt. (33).
Bramwell, J. H., Roanoke, Va. (33).
Brashear, Jno. A., 3 Holt St., Pittsburg, S. S., Pa. (33).
Bray, Prof. C. D., College Hill, Mass. (29).
Brayton, Miss Sarah H., M. D., Evanston, Ill. (33).
Breckinridge, S. M., P. O. Box 2794, St. Louis, Mo. (27).
Breidenbaugh, Prof. E. S., Pennsylvania College, Gettysburg, Pa. (33).
Brice, Judge Albert G., 122 Gravier St., New Orleans, La. (32).
Bridges, Henry Seabury, M.A., University of New Brunswick, Fredericton, N. B. (33).
Bringhurst, Prof. W. L., Agric. and Mechan. College of Texas, College Station, Brazos Co., Texas (32).
Brinton, Daniel G., M. D., Media, Pa. (33).
Brinton, J. Bernard, M. D., 755 Corinthian Ave., Philadelphia, Pa. (33).
Brissette, Milton H., Montreal, Can. (31).
Bromfield, Rev. Edw. T., Glenbrook, Fairfield Co., Conn. (33).
Bronnson, W. H., Lt. Comd'r U. S. N., Yonkers, N. Y. (31).
Bronson, E. H., Ottawa, Ontario, Can. (31).
Brooks, Miss Margarette W., Salem, Mass. (29).
Broomall, Hon. John M., Media, Delaware Co., Pa. (23).
Brosius, Lewis W., Cochranville, Chester Co., Pa. (33).
Broun, Albert P., Ph. D., 501 Federal St., Camden, N. J. (33).
Brownell, Prof. Walter A., 125 University Ave., Syracuse, N. Y. (30).
Brown, Miss Anna, 528 West 7th St., Cincinnati, Ohio (31).
Brown, Arthur, C. E., Oakland, Alameda Co., Cal. (31).
Brown, Mrs. Ashley, 115 Wilkinson St., Dayton, Ohio (25).
Brown, Prof. C. J., Randolph, N. Y. (31).
Brown, Fred. G., care of McKesson and Robbins, 93 Fulton St., New York, N. Y. (31).
Brown, Hon. John C., Vice President, Texas and Pacific R. R. Co., Pulaski, Tenn. (26).
Brown, Jonathan, 390 Broadway, Somerville, Mass. (29).

Brown, Paul Taylor, 2206 Green St., Philadelphia, Pa. (33).
Brühl, Gustav, N. W. cor. John and Hopkins Sts., Cincinnati, Ohio (28).
Buck, C. Elton, Wilmington, Del. (29).
Buck, Henry C., West Somerville, Mass. (29).
Buckingham, Chas. L., U. S. Patent Office, Washington, D. C. (28).
Budd, Henry I., Mount Holly, N. J. (33).
Buffum, Miss Fannie A., Linden, Mass. (29).
Bulloch, Walter H., 99 W. Monro St., Chicago, Ill. (30).
Burchard, Wm. M., M. D , Uncasville, Conn. (33).
Burdick, Edson A., 406 Spruce St., Le Droit Park, Washington, D. C. (30).
Burke, Jos. C., Middletown, Conn. (29).
Burke, William, U. S. Patent Office, Washington, D. C. (28).
Burland, Jeffrey H., Montreal, Can. (31).
Burns, Prof. James A., Box 456, Atlanta, Ga. (32).
Bush, Rev. Stephen, D. D., Waterford, N. Y. (19).
Butcher, Mrs. Z. D., Washington, D. C. (29).
Butler, A. W., Brookville, Franklin Co., Ind. (30).
Butler, Cyrus, 24 Cliff St., New York, N. Y. (29).
Butler, Nathan, 17 Johnston Block, Minneapolis, Minn. (32).
Butterfield, W. Webster, M. D., New Castle, Ind. (32).
Byrnes, R. M., M. D., cor. 5th and Race Sts., Cincinnati, Ohio (30).

Calder, Edwin E., Box 17, Providence, R. I. (29).
Caldwell, Albert G., Lt. Comd'r U. S. N., Torpedo Station, Newport, R. I. (31).
Caldwell, Dr. Frank, Cincinnati Hospital, Cincinnati, Ohio (30).
Calkins, Dr. Marshall, Springfield, Mass. (29).
Campbell, Rev. Prof. John, Presbyterian College, Montreal, Can. (31).
Campbell, Jos. Addison, 4816 Hancock St., Germantown, Pa. (33).
Canfield, Rev. Eli H., D.D., Arlington, Bennington Co., Vt. (25).
Capen, Miss Bessie T., Northampton, Mass. (23).
Cardeza, John M., M.D., Claymont, Del. (33).
Cargill, H. L., Hotel Eliot, Roxbury, Mass. (31).
Carman, Lewis, Bangall, N. Y. (29).
Caron, C. K., Louisville, Ky. (30).
Carpenter, Louis G., Agricultural College, Lansing, Mich. (32).
Carrington, Col. Henry B., U. S. A., care Adj. Gen. U. S. A., Washington, D. C. (20).
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Tracy, Will W., Detroit, Mich. (30).
Treadwell, Geo. A., Phœnix, Arizona (29).
Treat, Erastus B., Publisher and Bookseller, 771 Broadway, New York, N. Y. (29).
Treat, Mrs. Mary, Vineland, N. J. (33).
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Troop, James, Agricultural College, Lansing, Mich. (31).
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Vail, Prof. Hugh D., Santa Barbara, Cal. (18).
Valentine, Benj. B., Richmond, Va. (33).
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Vining, Edward P., Omaha, Neb. (32).
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Wallis, John M., C. E. (32).
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Walton, Jos. J. (29).
Walworth, Rev. Clarence A., Albany, N. Y. (28).
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Waring, John, Ovid, N. Y. (33).
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Weaver, Lemuel, Urbana, Ohio (32).
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Whitman, Gilbert P., Manchester, N. H. (30).
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Wilkinson, Mrs. L. V., Brazeau P. O., Perry Co., Mo. (30).
Willcox, Joseph, Media, Pa. (33).
Willetts, Joseph C., Skaneateles, N. Y. (29).
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Williams, J. Francis, Salem, N. Y. (31).
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Williams, P. O., M.D., Watertown, Jefferson Co., N. Y. (24).
Williamson, Prof. Andrew W., Rock Island, Ill. (32).
Willoughby, Hugh L., Saratoga Springs, N. Y. (28).
Wills, William R., Waltham, Mass. (30).
Willson, Prof. Frederick N., Princeton, N. J. (33).
Willson, Robert W., care Rev. E. B. Willson, Salem, Mass. (30).
Willson, Z. G. (32).
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Wilson, Horace E., 1514 10th St. N., Minneapolis, Minn. (32).
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Wilson, M. C., Florence, Ala. (26).
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Wisser, John P., 1st Lt. 1st Art'y, care Adj. Gen. U. S. A., Washington, D. C. (33).
Wister, Mrs. Caspar, 1303 Arch St., Philadelphia, Pa. (33).
Wister, Mrs. Owen J. (33).
Witherowe, James P., Pittsburgh, Pa. (33).
Withers, W. A., Raleigh, N. C. (33).
Wolcott, Mrs. Henrietta L. T., Dedham, Mass. (29).
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Young, A. V. E., Harvard Chemical Laboratory, Cambridge, Mass. (33).
Young, Prof. Andrew H., Hanover, Ind. (30).
Young, Chas. Ira, care Prof. C. A. Young, Princeton, N. J. (33).

Zimmerman, Charles D., Buffalo, N. Y. (30).
Zimmerman, William, 164 Dearborn St., Chicago, Ill. (30).

[1419 MEMBERS.]

NOTE.—The omission of an address in the foregoing list indicates that letters directed to that last printed were returned as uncalled for. Information of the present address of the members so indicated is requested by the PERMANENT SECRETARY.

## HONORARY FELLOW.[1]

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## FELLOWS.[2]

Abbe, Prof. Cleveland, Army Signal Office, Washington, D. C. (16). 1874.
Abbott, Dr. Chas. C., Trenton, N. J. (29). 1883.
Alexander, John S., 1935 Arch St., Philadelphia, Pa. (20). 1874.
Allen, Joel A., Am. Mus. of Nat. History, Central Park, New York. (18). 1875.
Alvord, Henry E., C. E., Houghton Farm, Mountainville, Orange Co., N. Y. (29). 1882.
Ammen, Daniel, Rear Admiral U. S. Navy, Ammendale, Prince George Co., Md. (26). 1881.
Anderson, Dr. Joseph, Waterbury, Conn. (29). 1883.
Anthony, Prof. Wm. A., Cornell Univ., Ithaca, N. Y. (28). 1880.
Arthur, J. C., Geneva, N. Y. (21). 1883.
Ashburner, Charles A., 907 Walnut St , Philadelphia, Pa. (31). 1883.
Ashburner, Wm., 1014 Pine St., San Francisco, Cal. (29). 1882.
Atkinson, Edward, 31 Milk St., Boston, Mass. (29). 1881.
Atwater, Prof. W. O., Wesleyan Univ., Middletown, Conn. (29). 1882.
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Bailey, Prof. W. W., Brown University,Providence, R. I. (18). 1874.
Baird, Prof. S. F., Sec'y Smithsonian Inst., Washington, D. C. (1). 1875.
Baker, Marcus, Coast and Geodetic Survey Office, Washington, D. C. (30). 1882.
Ballou, Geo. F., Hartford, Conn. (29). 1881.
BARKER, PROF. G. F., Univ. of Penn., Philadelphia, Pa. (13). 1875.
Barnard, Edward E., Observ. of Vanderbilt Univ., Nashville, Tenn. (26). 1883.
Barnard, F. A. P., President Columbia College, New York, N. Y. (7). 1874.
Barnard, Prof. Wm. S., U. S. Dept. Agric., Washington, D. C. (24). 1880.
Bartlett, Prof. Edwin J., Dartmouth College, Hanover, N. H. (28). 1883.

[1] See ARTICLE VI of the Constitution. [2] See ARTICLE IV of the Constitution.

*** The number in parenthesis indicates the meeting at which the member joined the Association; the date at the end of the line the time when made a Fellow.

When the name is given in small capitals, it designates that the Fellow is also a life member, and is entitled to the Annual Volume of Proceedings.

* Deceased.

Bartlett, John R., Comd'r U. S. N., Navy Dep't, Washington, D. C. (30). 1882.
Bassett, Homer F., Waterbury, Conn. (23). 1874.
Batchelder, Dr. J. H., Salem, Mass. (18). 1874.
Batchelder, John M., 3 Divinity Avenue, Cambridge, Mass. (8). 1875.
Bausch, Edward, Rochester, N. Y. (26). 1883.
Beal, Prof. Wm. James, Agricultural College, Ingham Co., Mich. (24). 1880.
Belknap, George E., Capt. U. S. N., care Fred. L. Wheeler & Co., Box 3522, Boston, Mass. (29). 1881.
Bell, Dr. Alex. Graham, Scott Circle, 1500 Rhode Island Ave., Washington, D. C. (26). 1879.
Bell, Samuel N., Manchester, N. H. (7). 1874.
Bessey, Prof. Charles E., Univ. of Nebraska, Lincoln, Neb. (21). 1880.
Bethune, Rev. C. J. S., Trinity Coll. School, Pt. Hope, Canada (18). 1875.
Beyer, Henry G., Passed Ass't Surgeon U. S. N., Bureau Med. and Surg., Navy Dep't, Washington, D. C. (31). 1884.
Bickmore, Prof. Albert S., American Museum of Natural History, 8th Ave. and 77th St., Central Park, New York, N. Y. (17). 1880.
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Blackham, George E., M. D., Dunkirk, N. Y. (25). 1883.
Blake, Clarence J., M. D., Hotel Berkeley, Boston, Mass. (24). 1877.
Blake, Eli W., New Haven, Conn. (1). 1874.
Blake, Prof. Eli W., jr., Brown Univ., Providence, R. I. (15). 1874.
Blake, Francis, Auburndale, Mass. (23). 1874.
Blake, Prof. John R., Greenwood, S. C. (29). 1884.
Bolton, Dr. H. Carrington, Trinity Coll., Hartford, Conn. (17). 1875.
Borden, Spencer, Fall River, Mass. (29). 1882.
Bouvé, Thos. T., Boston Soc. Nat. Hist., Boston, Mass. (1). 1875.
Bowditch, Prof. H. P., Jamaica Plain, Mass. (28). 1880.
Bowditch, Henry I., M.D., 113 Boylston St., Boston, Mass. (2). 1875.
Bowser, Prof. E. A., Rutgers College, New Brunswick, N. J. (28). 1881.
Brackett, Prof. C. F., College of New Jersey, Princeton, N. J. (19). 1875.
Brewer, Prof. Wm. H., New Haven, Conn. (20). 1875.
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Britton, N. L., Columbia College, New York, N. Y. (29). 1882.
Broadhead, Garland Carr, Pleasant Hill, Cass Co., Mo. (27). 1879.
Brooks, Major Thomas B., Geol. State Surveys, Mich. and Wis., Newburgh, N. Y. (26). 1879.
Bross, Hon. Wm., Tribune Office, Chicago, Ill. (7). 1874.
Brown, Robert, jr., care of Yale College Observatory, New Haven, Conn. (11). 1874.
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Burr, Prof. William H., Troy, N. Y. (31). 1883.
Burrill, Prof. T. J., Illinois Industrial Univ., Champaign, Ill. (29). 1882.

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Carpenter, Lieut. W. L., U. S. A., Dunkirk, N. Y. (24). 1877.
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Carr, Lucien, Peabody Mus. Arch. and Ethn., Cambridge, Mass. (25). 1877.
Case, Col. Theo. S., Ed. Western Review of Science, Kansas City, Mo. (27). 1883.
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Chanute, O., Kansas City, Mo. (17). 1877.
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Claypole, Prof. Edw. W., B. A., Buchtel Coll., Akron, Ohio. (30). 1882.
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Coffin, Prof. Selden J., Ph.D. Lafayette College, Easton, Pa. (22). 1874.
Collett, Prof. John, Chief Indiana Bureau of Statistics of Geology, Indianapolis, Ind. (17). 1874.
Colvin, Verplanck, Supt. N. Y. State Adirondack Survey, Albany, N. Y. (28). 1880.
Comstock, J. Henry, Cornell Univ., Ithaca, N. Y. (28). 1882.
Comstock, Milton L., Prof. Math., Knox Coll., Galesburg, Ill. (21). 1874.
Cook, Prof. A. J., Agricultural College, Lansing, Mich. (24). 1880.
Cook, Prof. George H., New Brunswick, N. J. (4). 1875.
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Crosby, Wm. O., Mass. Inst. Technology, Boston, Mass. (29). 1881.
Cross, Prof. Chas. R., Mass. Inst. Technology, Boston, Mass. (29). 1880.
Cummings, Rev. Joseph, D. D., Pres. Northwestern Univ., Evanston, Ill. (13). 1874.
Cutting, Hiram A., M. D., State Geologist, Lunenburgh, Vt. (17). 1874.

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Dall, Wm. H., Smithsonian Institution, Washington, D. C. (18). 1874.
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Dorsey, Rev. J. Owen, Bureau of Ethnology, Washington, D. C. (31). 1883.
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Du Bois, Prof. Aug. J., New Haven, Conn. (30). 1882.
Dudley, Charles B., Altoona, Pa. (23). 1882.
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Dudley, Prof. Wm. R., Ithaca, N. Y. (29). 1883.
Dunnington, Prof. F. P., University of Virginia, Va. (26). 1880.
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Fairchild, H. L., Sec'y N. Y. Acad. Sciences, 102 E. 52d St., New York, N. Y. (28). 1883.
Farlow, Dr. W. G., 29 Holyoke House, Boston, Mass. (20). 1875.
Farmer, Moses G., Torpedo Station, Newport, R. I. (9). 1875.
Ferguson, Maj. Thos. B., Ass't U. S. Fish Commissioner, Washington, D. C. (28). 1881.
Fernald, Prof. Chas. H., State Agric. College, Orono, Me. (22). 1881.
Fernald, Prof. M. C., State Agricultural College, Orono, Me. (22). 1883.
Ferrel, Wm., Army Signal Office, Washington, D. C. (11). 1875.
Ficklin, Prof. Joseph, Univ. of Missouri, Columbia, Mo. (20). 1878.
Fitch, Edward H., Jefferson, Ashtabula Co., Ohio (11). 1874.
Fletcher, Miss Alice C., care Peabody Museum, Cambridge, Mass. (29). 1883.
Fletcher, James, Library of Parliament, Ottawa, Can. (31). 1883.
Fletcher, Dr. Robert, Surgeon General's Office, U. S. A., Washington, D. C. (29). 1881.
Flint, James M., Surgeon U. S. N., 42 Dartmouth St., Boston, Mass. (28). 1882.
Foote, Dr. A. E., 1223 Belmont Avenue, Philadelphia, Pa. (21). 1874.
Forbes, Prof. S. A., Champaign, Ill. (27). 1879.
Foye, Prof. J. C., Lawrence Univ., Appleton, Wis. (29). 1884.
Frazer, Dr. Persifor, 917 Clinton St., Philadelphia, Pa. (24). 1879.

Frazier, Prof. B. W., The Lehigh University, Bethlehem, Pa. (24). 1882.
Freeman, H. C., Alto Pass, Union Co., Ill. (17). 1876.
Freeman, Spencer H., Adelbert College, Cleveland, Ohio (29). 1883.
French, Prof. Thomas, jr., No. 2 Chester Block, Auburn St., Cincinnati, Ohio (30). 1883.
Frisby, Prof. Edgar, U. S. N. Observ., Washington, D. C. (28). 1880.
Fuller, Andrew S., Ridgewood, Bergen Co., N. J. (24). 1882.

Gage, Simon Henry, Ithaca, N. Y. (28). 1881.
Gardiner, Rev. Frederic, D. D., Middletown, Conn. (23). 1874.
Gardiner, James T., Director N. Y. State Survey, Albany, N. Y. (25). 1879.
Garland, Rev. Dr. L. C., Chancellor Vanderbilt Univ., Nashville, Tenn. (25). 1877.
Garman, S., care Museum Comp. Zoology, Cambridge, Mass. (20). 1874.
Gatschet, Albert S., Bureau of Ethnology, Washington, D. C. (30). 1882.
Genth, Dr. F. A., Univ. of Pennsylvania, Philadelphia, Pa. (24). 1875.
Gilbert, G. K., Box 591, Washington, D. C. (18). 1874.
Gillman, Henry, Detroit, Mich. (24). 1875.
Gilman, Daniel C., Pres. Johns Hopkins Univ., Baltimore, Md. (10). 1875.
Goessman, Prof. C. A., Mass. Agric. Coll., Amherst, Mass. (18). 1875.
Goldschmidt, S. A., Ph. D., 55 Broadway, New York, N. Y. (24). 1880.
Gooch, Frank A., U. S. Geological Survey, Washington, D. C. (25). 1880.
Goodfellow, Edward, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (24). 1879.
Grant, Mrs. Mary J., Brookfield, Conn. (23). 1874.
Gratacap, L. P., Ph.B., 77th St. and 8th Ave., New York, N. Y. (27). 1884.
Gray, Prof. Asa, Botanic Gardens, Cambridge, Mass. (1). 1875.
Gray, Elisha, Ph. D., Highland Park, Ill. (32). 1883.
Green, Traill, M. D., Easton, Pa. (1). 1874.
Grimes, J. Stanley, 406 Sycamore St., Milwaukee, Wis. (17). 1874.
Grinnan, A. G., Rapidan Station, Va. Mid. R. R., Va. (7). 1875.
Gulley, Prof. Frank A., Agricultural College, Oktibbeha Co., Miss. (30). 1883.

Hagen, Dr. Hermann A., Mus. Comp. Zool., Cambridge, Mass. (17). 1875.
Hague, Arnold, 10 West 29th St., New York, N. Y. (26). 1879.
Hale, Horatio, Clinton, Ontario, Can. (30). 1882.
Hall, Prof. Asaph, U. S. Naval Observ., Washington, D. C. (25). 1877.
Hall, Prof. C. W., Univ. of Minnesota, Minneapolis, Minn. (28). 1883.
Hall, Prof. Edwin H., 5 Avon St., Cambridge, Mass. (29). 1881.
Hall, Prof. James, Albany, N. Y. (1). 1875.
Hall, Prof. Lyman B., Haverford College, Pa. (31). 1884.
Halsted, Byron D., Agricultural College, Ames, Iowa (29). 1883.
Hamlin, Dr. A. C., Bangor, Me. (10). 1874.
Hanaman, C. E., Troy, N. Y. (19). 1883.
Hardy, Prof. A. S., Dartmouth College, Hanover, N. H. (28). 1883.
Harger, Oscar, Yale College Museum, New Haven, Conn. (25). 1879.
Harkness, Prof. Wm., U. S. N. Observ., Washington, D. C. (26). 1878.

Harrington, Prof. Mark W., Ann Arbor, Mich. (22). 1875.
Harrison, Dr. B. F., Wallingford, Conn. (11). 1874.
Hasbrouck, Prof. I. E., Rutgers Coll., New Brunswick, N. J. (28). 1874.
Hastings, C. S., Sheffield Sci. School of Yale College, New Haven, Conn. (25). 1878.
Hayden, Dr. F. V., 1910 Arch St., Philadelphia, Pa. (29). 1881.
Haynes, Henry W., 239 Beacon St., Boston, Mass. (28). 1884.
Hazen, Wm. B., Brig. and B'vt. Maj. Gen'l, Chief Signal Officer, U. S. A., Washington, D. C. (30). 1882.
Hedrick, B. S., Exam'r U. S. Patent Office, Washington, D. C. (19). 1874.
Henshaw, Henry W., Care Major J. W. Powell, 910 M St., Washington, D. C. (24). 1877.
Herrick, Clarence L., Granville, Ohio (31). 1884.
Hervey, Rev. A. B., Taunton, Mass. (22). 1879.
Hilgard, Prof. E. W., Univ. of California, Berkeley, Cal. (11). 1874.
Hilgard, Prof. J. E., U. S. Coast Survey, Washington, D. C. (4). 1874.
Hill, Franklin C., P. O. Box 338, Princeton, N. J. (29). 1881.
Hill, George W., Nautical Almanac Office, Navy Department, Washington, D. C. (23). 1874.
Hill, Rev. Dr. Thomas, 738 Congress St., Portland, Me. (3). 1875.
Himes, Prof. Charles F., Carlisle, Pa. (29). 1882.
Hinrichs, Prof. Gustavus, State University, Iowa City, Iowa (17). 1874.
Hitchcock, Prof. Charles H., Hanover, N. H. (11). 1874.
Hitchcock, Romyn, Washington, D. C. (29). 1881.
Hoadley, J. C., 28 State St., Room 28, Boston, Mass. (29). 1884.
Hodges, N. D. C., Salem, Mass. (29). 1882.
Hoffman, Dr. Fred., 183 Broadway, New York, N. Y. (28). 1881.
Holden, Prof. E. S., Director Washburn Observatory, Univ. of Wisconsin, Madison, Wis. (23). 1875.
Holman, Silas W., Mass. Inst. of Technology, Boston, Mass. (31). 1883.
Holmes, Dr. Oliver Wendell, 296 Beacon St., Boston, Mass. (29). 1881.
Holmes, Wm. H., Smithsonian Institution, Washington, D. C. (30). 1883.
Horsford, Prof. E. N., Cambridge, Mass. (1). 1876.
Hosea, Lewis M., Johnston Building, Cincinnati, Ohio (30). 1883.
Hotchkiss, Jed., Staunton, Va. (31). 1883.
Hough, Franklin B., Lowville, N. Y. (4). 1874.
Hough, G. W., Director Dearborn Observatory, Chicago, Ill. (15). 1874.
Hovey. Rev. Horace C., 1519 Park Ave., Minneapolis, Minn. (29). 1883.
Hoy, Philo R., M. D., Racine, Wis. (17). 1875.
Hunt, George, Providence, R. I. (9). 1874.
Hunt, Dr. T. Sterry, Montreal, Canada (1). 1874.
Huntington, Prof. J. H., Boston, Mass. (19). 1874.
Hyatt, Prof. Alpheus, Natural History Society, Boston, Mass. (18). 1875.
Hyatt, James, Stanfordville, Duchess Co., N. Y. (10). 1874.
Hyde, Prof. E. W., Walnut Hills, Cincinnati, Ohio (25). 1881.

Iddings, Joseph P., U. S. Geol. Survey, Washington, D. C. (31). 1884.
Irving, Roland D., Wis. State Geol. Survey, Madison, Wis. (26). 1879.

James, Jos. F., 108 Broadway, Cincinnati, Ohio (30). 1882.
Jayne, Horace F., 1826 Chestnut St., Philadelphia, Pa. (29). 1884.
Jeffries, B. Joy, M. D., 15 Chestnut St., Boston, Mass. (29). 1881.
Jenks, Elisha T., Middleborough, Mass. (22). 1874.
Jenks, Prof. J. W. P., Middleborough, Mass. (2). 1874.
Jewell, Theo. F., Lt. Comdr. U. S. N., Torpedo Station, Newport, R. I. (25). 1882.
Jillson, Dr. B. C., Illinois Industrial Univ., Champaign, Ill. (14). 1881.
Johnson, Prof. S. W., 54 Trumbull St., New Haven, Conn. (22). 1874.
Johnson, Prof. W. W., Naval Acad., Annapolis, Md. (29). 1881.
Joy, Prof. Charles A., care F. Hoffmann, Stockbridge, Mass. (8). 1879.
Julien, A. A., School of Mines, Columbia Coll., New York, N. Y. (24). 1875.

Kedzie, Prof. Robert C., Lansing, Mich. (29). 1881.
Kellicott, David S., Buffalo, N. Y. (31). 1883.
Kendall, Prof. E. Otis, 3826 Locust St., Philadelphia, Pa. (29). 1882.
Kennan, George, 1318 Mass. Avenue, Washington, D. C. (30). 1882.
Kent, William, 30 Cortlandt St., New York, N. Y. (26). 1881.
Kerr, Prof. W. C., Raleigh, N. C. (10). 1874.
Kershner, Prof. Jefferson E., Lancaster City, Pa. (29). 1883.
Kinnicutt, Leonard P., 5 Chestnut St., Worcester, Mass. (28). 1883.
Kirkwood, Prof. Daniel, Bloomington, Ind. (7). 1874.
Kunz, G. F., with Tiffany and Co., New York, N. Y. (29). 1883.

Lambert, Rev. Thomas R., D.D., Charlestown, Mass. (18). 1874.
Landreth, Prof. Olin H., Vanderbilt Univ., Nashville, Tenn. (28). 1883.
Langdon, Dr. F. W., 65 West 7th St., Cincinnati, Ohio (30). 1882.
Langley, Prof. J. W., Univ. of Michigan, Ann Arbor, Mich. (23). 1875.
Langley, Prof. S. P., Director of Observatory, Allegheny, Pa. (18). 1874.
Lanza, Prof. Gaetano, Mass. Inst. of Technology, Boston, Mass. (29). 1882.
Larkin, Edgar L., New Windsor, Mercer Co., Ill. (28). 1883.
Lattimore, Prof. S. A., Univ. of Rochester, Rochester, N. Y. (15). 1874.
Lawrence, George N., 45 E. 21st St., New York, N. Y. (7). 1877.
Lazenby, Prof. Wm. R., Ithaca, N. Y. (30). 1882.
Lea, Dr. Isaac, 1622 Locust St., Philadelphia, Pa. (1). 1875.
LeConte, Prof. Joseph, Univ. of Cal., Berkeley, Cal. (29). 1881.
Ledoux, Albert R., Ph. D., 10 Cedar St., New York, N. Y. (26). 1881.
Leeds, Prof. Albert R., Stevens Institute, Hoboken, N. J. (23). 1874.
Leonard, N. R., State Univ., Iowa City, Iowa (21). 1875.
Lesley, Prof. J. Peter, State Geol. of Pa., 1008 Clinton St., Philadelphia, Pa. (2). 1874.
Lewis, Prof. H. Carvill, High St., Germantown, Pa. (26). 1880.
Lilly, Gen. Wm., Mauch Chunk, Carbon Co., Pa. (28). 1882. Patron.

Lintner, J. A., N. Y. State Entomologist, Room 27, Capitol, Albany, N. Y. (22). 1874.
Litton, Abram, 2220 Eugenia St., St. Louis, Mo. (28). 1879.
Lockwood, Rev. Samuel, Freehold, Monmouth Co., N. J. (18). 1875.
Loomis, Prof. Elias, New Haven, Conn. (1). 1874.
Lord, Prof. Nat. W., State Univ., Columbus, Ohio (29). 1881.
Loudon, Prof. James, Toronto, Can. (25). 1881.
Loughridge, Prof. R. H., Ass't State Geol., Frankfort, Ky. (21). 1874.
Love, Edward G., School of Mines, Columbia College, New York, N. Y. (24). 1882.
Lovering, Prof. Joseph, Harvard University, Cambridge, Mass. (2). 1875.
Lull, Edward P., Captain U. S. N., care Navy Dep't, Washington, D. C. (28). 1880.
Lupton, Prof. N. T., Vanderbilt University, Nashville, Tenn. (17). 1874.
Lyle, David Alexander, Capt. of Ordnance U. S. A., National Armory, Springfield, Mass. (28). 1880.
Lyman, Prof. Chester S., New Haven, Conn. (4). 1875.
Lyman, Hon. Theodore, Brookline, Mass. (23). 1875.
Lyon, Dr. Henry, 34 Monument Sq., Charlestown, Mass. (18). 1874.

Mabery, Prof. C. F., Case School of Applied Science, Cleveland, Ohio (29). 1881.
Macfarlane, James, Towanda, Pa. (29). 1882.
Mackintosh, James B., School of Mines, Columbia College, New York, N. Y. (27). 1883.
Macloskie, Prof. George, College of New Jersey, Princeton, N. J. (25). 1882.
Mallery, Brevet Lieut. Col. Garrick, U. S. Army, Box 585, Washington, D. C. (26). 1879.
Mann, B. Pickman, U. S. Dep't of Agric., Washington, D. C. (22). 1874.
Marcy, Oliver, LL.D., Evanston, Ill. (10). 1874.
Markoe, Geo. F. H., 61 Warren St., Roxbury, Mass. (29). 1881.
Marsh, Prof. O. C., Yale College, New Haven, Conn. (15). 1874.
Martin, Prof. Daniel S., 236 West 4th St., New York, N. Y. (28). 1879.
Martin, Prof. H. Newell, Johns Hopkins Univ., Baltimore, Md. (27). 1880.
Martin, Prof. Wm. J., Davidson College, N. C. (31). 1884.
Mason, Prof. Otis T., Columbian University, Washington, D. C. (25). 1877.
Mayer, Prof. A. M., So. Orange, N. J. (19). 1874.
McCauley, Capt. C. A. H., Ass't Q. M., U. S. A., 321 Michigan Ave., Chicago, Ill. (29). 1881.
McGee, W. J., U. S. Geol. Survey, Washington, D. C. (27). 1882.
McMurtrie, William, Ill. Indust. Univ., Champaign, Ill. (22). 1874.
McNair, Lt. Commander Antoine R., U. S. N., Box 1071, Saratoga Springs, N. Y. (28). 1882.
McRae, Hamilton S., Supt. of Schools, Marion, Ind. (20). 1874.
Meehan, Thomas, Germantown, Pa. (17). 1875.
Mees, Carl Leo, Columbus, Ohio (24). 1876.

Mendenhall, Prof. T. C., U. S. Signal Service, Washington, D. C. (20) 1874.
Merriman, C. C., Rochester, N. Y. (29). 1880.
Michelson, A. A., Master U. S. N., 7 Rockwell St., Cleveland, Ohio (26). 1879.
Minot, Dr. Charles Sedgwick, 25 Mt. Vernon St., Boston, Mass. (28). 1880.
Minot, Francis, M. D., 65 Marlborough St., Boston, Mass. (29). 1884.
Mitchell, Miss Maria, Vassar College, Poughkeepsie, N. Y. (4). 1874.
Mixter, Prof. Wm. G., New Haven, Conn. (30). 1882.
Moore, Prof. J. W., M. D., Lafayette College, Easton, Pa. (22). 1874.
Morley, Prof. Edward W., 749 Republic St., Cleveland, Ohio (18). 1876.
Morris, Rev. John G., Baltimore, Md. (12). 1874.
Morse, Prof. E. S., Salem, Mass. (18). 1874.
Morton, H., Stevens Institute Technology, Hoboken, N. J. (18). 1875.
Moses, Prof. Thos. F., Urbana Univ., Urbana, Ohio (25). 1883.
Munroe, Prof. C. E., U. S. Naval Academy, Annapolis, Md. (22). 1874.
Murtfeldt, Miss Mary E., Kirkwood, Mo. (27). 1881.

Nason, Prof. H. B., Rensselaer Polytechnic Inst., Troy, N. Y. (13). 1874.
Neale, Arthur T., Ph. D., New Brunswick, N. J. (29). 1882.
Nelson, Prof. A. B., Centre College, Danville, Ky. (30). 1882.
Nelson, Prof. Edward T., Delaware, Delaware Co., Ohio (24). 1877.
Newberry, Prof. J. S., Columbia College, New York, N. Y. (5). 1875.
Newcomb, Prof. S., Navy Dep't, Washington, D. C. (13). 1874.
Newton, Hubert A., New Haven, Conn. (6). 1874.
Nichols, E. L., Ph. D., Univ. of Kansas, Lawrence, Kansas (28). 1881.
Nichols, Prof. W. R., Mass. Inst. Technology, Boston, Mass. (18). 1875.
Niles, Prof. W. H., Cambridge, Mass. (16). 1874.
Nipher, Prof. F. E., Washington University, St. Louis, Mo. (24). 1876.

Oliver, Prof. James E., Cornell University, Ithaca, N. Y. (7). 1875.
Oliver, Miss Mary E., Cascadilla Hotel, Ithaca, N. Y. (20). 1874.
Ordway, Prof. John M., Tulane Univ., New Orleans, La. (9). 1875.
Orton, Prof. Edward, President Ohio Agricultural and Mechanical College, Columbus, Ohio (19). 1875.
Osborn, Henry F., S. D., Garrisons, N. Y. (29). 1883.
Osborn, Herbert, Ames, Iowa (32). 1884.
Osborne, J. W., 212 Delaware Ave. N. E., Washington, D. C. (22). 1874.
Osler, Prof. William, McGill College, Montreal, Canada (28). 1881.
Owen, Dr. Richard, New Harmony, Ind. (20). 1874.

Packard, Dr. A. S., 115 Angell St., Providence, R. I. (16). 1875.
Paine, Cyrus F., 242 East Ave., Rochester, N. Y. (12). 1874.
Paine, Nathaniel, Worcester, Mass. (18). 1874.
Palfray, Hon. Charles W., Salem, Mass. (21). 1874.

Parke, John G., Lt. Col. Corps of Eng'rs, Bv't Maj. Gen. U. S. A., Office of Chief of Engineers, Washington, D. C. (29). 1881.
Parkhurst, H. M., Law Stenographer, 25 Chambers St., New York, N. Y. (23). 1874.
Payne, Prof. Wm. W., Carleton College Observ., Northfield, Minn. (30). 1888.
Peckham, S. F., Providence, R. I. (18). 1875.
Pedrick, Wm. R., Lawrence, Mass. (22). 1875.
Peet, Rev. Stephen D., Clinton, Wis. (24). 1881.
Peirce, Prof. James M., Cambridge, Mass. (28). 1881.
Penhallow, Prof. D. P., McGill College, Montreal, Can. (30). 1882.
Perkins, Prof. George H., Burlington, Vt. (17). 1882.
Perkins, Maurice, Schenectady, N. Y. (15). 1875.
Peter, Dr. Robert, Ky. Geol. Survey, Lexington, Ky. (29). 1881.
Pettee, Prof. William H., Ann Arbor, Mich. (24). 1875.
Phillips, A. W., New Haven, Conn. (24). 1879.
Phippen, Geo. D., Salem, Mass. (18). 1874.
Pickering, Prof. E. C., Director of Observ., Cambridge, Mass. (18). 1875.
Pickering, William H., Inst. Technology, Boston, Mass. (29). 1883.
Pike, Dr. William H., University College, Toronto, Can. (29). 1881.
Pilling, James C., Box 591, Washington, D. C. (28). 1882.
Platt, Franklin, Ass't Geologist, 2nd Geol. Survey of Pa., 615 Walnut St., Philadelphia, Pa. (27). 1882.
Pohlman, Dr. Julius, Buffalo, N. Y. (32). 1884.
Potter, Prof. William B., Washington Univ., St. Louis, Mo. (25). 1879.
Powell, Major J. W., U. S. Geologist, 910 M St., Washington, D. C. (23). 1875.
Prentiss, D. Webster, M. D., 1224 9th St., N. W., Washington, D. C. (29). 1882.
Prescott, Prof. Albert B., Ann Arbor, Mich. (23). 1875.
Pritchett, Henry S., Observatory, Washington Univ., St. Louis, Mo. (29). 1881.
Pulsifer, Wm. H., St. Louis, Mo. (26). 1879.
Pumpelly, Prof. Raphael, U. S. Geol. Survey, Newport, R. I. (17). 1875.
Putnam, F. W., Curator Peabody Museum American Archæology and Ethnology, Cambridge, Mass. Address as Permanent Secretary A. A. A. S., Salem, Mass. (10). 1874.
Pynchon, Rev. T. R., Pres't Trinity Coll., Hartford, Conn. (23). 1875.

Quincy, Edmund, 88 Clinton St., Boston, Mass. (11). 1874.

Rauch, Dr. John H., Chicago, Ill. (11). 1875.
Raymond, Rossiter W., 17 Burling Slip, New York, N. Y. (15). 1875.
Redfield, J. H., care A. Whitney & Sons, Philadelphia, Pa. (1). 1874.
Reed, E. Baynes, London, Ontario, Can. (27). 1882.
Rees, Prof. John K., Columbia College, New York, N. Y. (26). 1878.
Remsen, Prof. Ira, Johns Hopkins University, Baltimore, Md. (22). 1875.

Rice, John M., U. S. Naval Academy, Annapolis, Md. (25). 1881.
Rice, Prof. Wm. North, Middletown, Conn. (18). 1874.
Richards, Prof. Robert H., Mass. Inst. Tech., Boston, Mass. (22). 1875.
Richards, Mrs. Robert H., Mass. Inst. of Tech., Boston, Mass. (23). 1878.
Richardson, Clifford, Dept. of Agric., Washington, D. C. (30). 1884.
Ricketts, Pierre de Peyster, Ph. D., 10 Cedar St., New York, N. Y. (26). 1880.
RILEY, PROF. C. V., U. S. Entomologist, 1700 13th St. N. W., Washington, D. C. (17). 1874.
Ritchie, E. S., 87 Franklin St., Boston, Mass. (10). 1877.
Robinson, Prof. S. W., Univ. of Ohio, Columbus, Ohio (30). 1883.
Rockwell, Gen. Alfred P., Office Great Falls Manufacturing Co., Boston, Mass. (10). 1882.
Rockwell, Chas. H., Box 293, Tarrytown, N. Y. (28). 1883.
Rockwood, Prof. Charles G., jr., College of New Jersey, Princeton, N. J. (20). 1874.
Rogers, Fairman, 202 West Rittenhouse Square, Philadelphia, Pa. (11). 1874.
Rogers, W. A., Ass't Prof. Harvard College Observ., Cambridge, Mass. (15). 1875.
Rominger, Dr. Carl, Ann Arbor, Mich. (21). 1879.
Rood, Prof. O. N., Columbia College, New York, N. Y. (14). 1875.
Roosevelt, Clinton, 11 Wall St., New York, N. Y. (11). 1874.
Rosenspitz, Dr. Alexander, Rabbi, Lock Box 430, Portland, Oregon (26). 1883.
Ross, Waldo O., 189 Devonshire St., Boston, Mass. (29). 1882.
Rowland, Prof. Henry A., Baltimore, Md. (29). 1880.
Runkle, Prof. J. D., Mass. Inst. of Tech., Boston, Mass. (2). 1875.
Russell, I. C., U. S. Geological Survey, Washington, D. C. (25). 1882.
Rutherford, Lewis M., 175 Second Ave., New York, N. Y. (13). 1875.

Sadtler, Prof. Saml. P., Univ. of Pa., Philadelphia, Pa. (22). 1875.
Safford, Dr. James M., Nashville, Tenn. (6). 1875.
Sampson, Com'd W. T., U.S.N., Torpedo Station, Newport, R. I. (25). 1881.
Saunders, William, London, Ontario, Canada (17). 1874.
Schanck, Prof. J. Stillwell, Princeton, New Jersey (4). 1882.
Schott, Charles A., U. S. Coast and Geodetic Survey Office, Washington, D. C. (8). 1874.
Schweitzer, Prof. Paul, State Univ. of Mo., Columbia, Mo. (24). 1877.
SCUDDER, SAMUEL H., Cambridge, Mass. (13). 1874.
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Seiler, Carl, M. D., Philadelphia, Pa. (29). 1882.
Sestini, Rev. B., Woodstock, Md. (29). 1882.
Sharples, Stephen P., 13 Broad St., Boston, Mass. (29). 1884.
Sheafer, P. W., Pottsville, Pa. (4). 1879.

Sias, Solomon, M. D., Schoharie, Schoharie Co., N. Y. (10). 1874.
Sill, Hon. Elisha N., Cuyahoga Falls, Ohio (6). 1874.
Silliman, Prof. Justus M., Lafayette College, Easton, Pa. (19). 1874.
Skinner, Joseph J., Ithaca, N. Y. (23). 1880.
Smiley, Charles W., 1443 Mass. Ave., Washington, D. C. (28). 1883.
Smith, Prof. Eug. A., University of Alabama, Tuscaloosa, Ala. (20). 1877.
Smith, Edwin, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (30). 1882.
Smith, Mrs. Erminnie A., 203 Pacific Ave., Jersey City, N. J. (25). 1880.
Smith, Prof. Francis H., Univ. of Virginia, Charlottesville, Va. (26). 1880.
Smith, Quintius C., M. D., No. 704 Congress Ave., Austin, Texas (26). 1881.
Smith, Prof. S. I., Yale College, New Haven, Conn. (18). 1875.
Smock, Prof. John Conover, New York State Museum, Albany, N. Y. (23). 1879.
Snow, Prof. F. H., Lawrence, Kan. (29). 1881.
Snyder, Prof. Monroe B., High School Observatory, Philadelphia, Pa. (24). 1882.
Spencer, Prof. J. William, Univ. of Missouri, Columbia, Mo. (28). 1882.
Spencer, John W., Geol., Paxton, Sullivan Co., Ind. (20). 1874.
Springer, Dr. Alfred, Box 579, Cincinnati, Ohio (24). 1880.
Stallo, J. B., Masonic Temple, Cincinnati, Ohio (30). 1882.
Stanard, Benjamin A., Cleveland, Ohio (6). 1874.
Stearns, R. E. C., care Smithsonian Inst., Washington, D. C. (18). 1874.
Steiner, Dr. Lewis H., Enoch Pratt Free Library, Baltimore, Md. (7). 1874.
Stephens, W. Hudson, Lowville, N. Y. (18). 1874.
Sternberg, George M., Surgeon U. S. A., Johns Hopkins Univ., Baltimore, Md. (24). 1880.
Stevens, W. LeConte, 170 Joralemon St., Brooklyn, N. Y. (29). 1882.
Stockwell, John N., 1008 Case Avenue, Cleveland, Ohio (18). 1875.
Stone, George H., Colorado Springs, Col. (29). 1882.
Stone, Mrs. Leander, 3352 Indiana Avenue, Chicago, Ill. (22). 1874.
Stone, Ormond, Director Leander McCormick Observatory, Univ. of Va., Va. (24). 1876.
Storrs, Henry E., Jacksonville, Ill. (20). 1874.
Story, Wm. E., Johns Hopkins Univ., Baltimore, Md. (29). 1881.
Stuart, Prof. A. P. S., Lincoln, Nebraska (21). 1874.
Sturtevant, E. Lewis, M. D., Geneva, N. Y. (29). 1882.
Sutton, Dr. George, Aurora, Dearborn Co., Ind. (20). 1881.
Swift, Lewis, Ph. D., Rochester, N. Y. (29). 1882.

Tainter, Sumner, 1221 Connecticut Ave., Washington, D. C. (29). 1881.
Tappan, Prof. Eli T., Kenyon College, Gambier, Ohio (20). 1874.
Taylor, Wm. B., Smithsonian Institution, Washington, D. C. (29). 1881.
Terry, Prof. N. M., U. S. Naval Academy, Annapolis, Md. (23). 1874.

Thomas, Benj. F., Ph. D., Univ. State of Missouri, Columbia, Mo. (29). 1882.
Thomas, Prof. Cyrus, Carbondale, Ill. (30). 1882.
Thurston, Prof. R. H., Stevens Institute, Hoboken, N. J. (23). 1875.
Todd, Prof. David P., Director Lawrence Observatory, Amherst College, Amherst, Mass. (27). 1881.
Townshend, Prof. N. S., Ohio State Univ., Columbus, Ohio (17). 1881.
Tracy, Sam'l M., Columbia, Boone Co., Mo. (27). 1881.
Trembley, J. B., M. D., 952 8th St., Oakland, Alameda Co., Cal. (17). 1880.
Trowbridge, Prof. John, Harvard University, Cambridge, Mass. (25). 1876.
Trowbridge, Prof. W. P., New Haven, Conn. (10). 1874.
True, Fred W., U. S. National Museum, Washington, D. C. (28). 1882.
Trumbull, Dr. J. Hammond, Hartford, Conn. (29). 1882.
Tuttle, Prof. Albert H., Columbus, Ohio (17). 1874.

Uhler, Philip R., 218 W. Hoffman St., Baltimore, Md. (19). 1874.
Upham, Warren, Nashua, N. H. (25). 1880.
Upton, Winslow, Brown Univ., Providence, R. I. (29). 1883.

Van der Weyde, P. H., M.D., Box 3619, New York, N. Y. (17). 1874.
Van Dyck, Prof. Francis Cuyler, New Brunswick, N. J. (28). 1882.
Van Vleck, Prof. John M., Middletown, Conn. (23). 1875.
Verrill, Prof. A. E., Yale College, New Haven, Conn. (16). 1875.
Vose, Prof. George L., Mass. Inst. Technology, Boston, Mass. (15). 1875.

Wachsmuth, Charles, Burlington, Iowa (30). 1884.
Wadsworth, M. Edward, Ph. D., Assistant in Lithology, Museum of Comparative Zoology, Cambridge, Mass. (23). 1874.
Walcott, Charles D., Natl. Museum, Washington, D. C. (25). 1882.
Waldo, Leonard, S. D., New Haven, Conn. (28). 1880.
Walker, J. R., D. D. S., Bay Saint Louis, Hancock Co., Miss. (19). 1874.
Wallace, Wm., Ansonia, Conn. (28). 1882.
Waller, E., School of Mines, Columbia College, New York, N. Y. (23). 1874.
Walling, H. F., Cambridge, Mass. (16). 1874.
Walmsley, W. H., 1016 Chestnut St., Philadelphia, Pa. (28). 1883.
Ward, Prof. Henry A., Rochester, N. Y. (13). 1875.
Ward, Lester F., U. S. Geological Survey, Washington, D. C. (26). 1879.
Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17). 1874.
Warder, Prof. Robert B., Lafayette, Ind. (19). 1881.
Warner, James D., 199 Baltic St., Brooklyn, N. Y. (18). 1874.
Warren, Cyrus M., Brookline, Mass. (29). 1882.
Warren, Prof. S. Edward, Newton, Mass. (17). 1875.
Watson, Sereno, Botanic Gardens, Cambridge, Mass. (22). 1875.

WATSON, PROF. WM. 107 Marlborough St., Boston, Mass. (12). 1884.
Wead, Prof. Charles K., Univ. of Mich., Ann Arbor, Mich. (23). 1880.
Webb, Prof. J. Burkitt, Cornell University, Ithaca, N. Y. (31). 1883.
Webster, Prof. H. E., Union College, Schenectady, N. Y. (28). 1882.
Webster, Prof. N. B., Principal Webster Inst., Norfolk, Va. (7). 1874.
Wells, Daniel H., Hartford, Conn. (18). 1875.
Westcott, O. S., Maywood, Cook Co., Ill. (21). 1874.
Wheatland, Dr. Henry, President Essex Inst., Salem, Mass. (1). 1874.
Wheeler, Prof. C. Gilbert, 81 Clark St., Chicago, Ill. (18). 1883.
Wheeler, Capt. Geo. M., U. S. E., Lock Box 93, Washington, D. C. (25). 1879.
Wheeler, Orlando B., Ass't U.S. Lake Survey, Detroit, Mich. (24). 1882.
Wheildon, W. W., Box 229, Concord, Mass. (13). 1874.
White, Prof. C. A., Le Droit Park, Washington, D. C. (17). 1875.
White, Prof. I. C., Univ. of W. Va., Morgantown, W. Va. (25). 1882.
Whitfield, R. P., American Museum Natural History, 77th St. & 8th Avenue, New York, N. Y. (18). 1874.
Whiting, Miss Sarah F., Wellesley College, Wellesley, Mass. (31). 1883.
Whitney, Solon F., Watertown, Mass. (20). 1874.
Whittlesey, Col. Charles, 1305 Euclid Ave., Cleveland, Ohio (1). 1875.
Wilber, G. M., Pine Plains, N. Y. (19). 1874.
Wilbur, A. B., Port Jervis, Orange Co., N. Y. (28). 1874.
Wilder, Prof. Burt G., Cornell University, Ithaca, N. Y. (22). 1875.
Wiley, Prof. Harvey W., Dept. of Agric., Washington, D. C. (21). 1874.
Williams, Charles H., M. D., 15 Arlington St., Boston, Mass. (22). 1874.
Williams, Henry Shaler, Cornell Univ., Ithaca, N. Y. (18). 1882.
Williams, Prof. Henry W., 15 Arlington St., Boston, Mass. (11). 1874.
Wilson, Prof. Daniel, President University College, 117 Bloor St., Toronto, Canada (25). 1876.
Winchell, Prof. Alex., Ann Arbor, Mich. (3). 1875.
Winchell, Prof. N. H., Univ. of Minnesota, Minneapolis, Minn. (19). 1874.
Woerd, Chas. V., Am. Watch Co., Waltham, Mass. (29). 1881.
Wood, Prof. De Volson, Hoboken, N. J. (29). 1881.
Woodbury, C. J. H., 31 Milk St., Boston, Mass. (29). 1884.
Woodward, Prof. Calvin M., 1761 Missouri Ave., St. Louis, Mo. (32). 1884.
Wormley, T. G., Univ. of Pennsylvania, Philadelphia, Pa. (20). 1878.
Worthen, A. H., Springfield, Ill. (5). 1874.
Wright, Prof. Albert A., Oberlin College, Oberlin, Ohio (24). 1880.
Wright, Prof. Arthur W., Yale College, New Haven, Conn. (14). 1874.
Wright, Rev. Geo. F., Oberlin College, Oberlin, Ohio (29). 1882.
Wurtele, Rev. Louis C., Acton Vale, Province of Quebec, Can. (11). 1875.
Wyckoff, Wm. C., 44 Howard St., New York (20). 1874.
Wylie, Prof. Theoph. A., Indiana Univ., Bloomington, Ind. (20). 1874.

Youmans, Prof. Edward L., New York, N. Y. (6). 1874.

Young, C. A., Prof. of Astronomy, College of New Jersey, Princeton, New Jersey (18). 1874.

Zentmayer, Joseph, 147 So. Fourth St., Philadelphia, Pa. (29). 1882.

[ 562 FELLOWS.]

TOTAL NUMBER OF MEMBERS OF THE ASSOCIATION, 1881.

# DECEASED MEMBERS.

[Information respecting omissions in this list, and the date of birth and of decease of any of the former members, is requested by the Permanent Secretary.]

Abbe, George W., New York, N. Y. (23). Died Sept. 25, 1879.

Abert, J. J., Washington, D. C. (1). Born in 1785. Died January 27, 1863.

Adams, C. B., Amherst, Mass. (1). Born January 11, 1814. Died Jan'y 19, 1853.

Adams, Edwin F., Charlestown, Mass. (18).

Adams, Samuel, Jacksonville, Ill. (18). Born Dec. 19, 1806. Died April 29, 1877.

Agassiz, Louis, Cambridge, Mass. (1). Born May 28, 1807. Died Dec. 14, 1873.

Ainsworth, J. G., Barry, Mass. (14).

Alexander, Stephen, Princeton, N. J. (1). Born Sept. 1, 1806. Died June 25, 1883.

Allen, Thomas, St. Louis, Mo. (27). Died April 8, 1882.

Allen, Zachariah, Providence, R. I. (1). Died March 17, 1882.

Allston, R. F. W., Georgetown, S. C. (8). Born April 21, 1801. Died April 7, 1864.

Alvord, Benjamin, Washington, D. C. (17). Died Oct. 16, 1884, at the age of 71.

Ames, M. P., Springfield, Mass. (1). Born in 1803. Died April 23, 1847.

Andrews, Ebenezer B., Lancaster, Ohio (7). Died Aug. 21, 1880, aged 59.

Anthony, Charles H., Albany, N. Y. (6). Died in 1874.

Appleton, Nathan, Boston, Mass. (1). Born Oct. 6, 1779. Died July 14, 1861.

Armstrong, John W., Fredonia, N. Y. (24).

Atwater, Mrs. S. T., Chicago, Ill. (17). Born Aug. 8, 1812. Died April 11, 1878.

Aufrecht, Louis, Cincinnati, Ohio (30).

Bache, Alexander D., Washington, D. C. (1). Born July 19, 1806. Died Feb. 17, 1867.

Bache, Franklin, Philadelphia, Pa. (1). Born Oct. 25, 1792. Died March 19, 1864.

Bailey, Jacob W., West Point, N. Y. (1). Born April 29, 1811. Died Feb. 26, 1857.

Bardwell, F. W., Lawrence, Kan. (13). Died in 1878.

Barnard, John G., New York, N. Y. (14). Died May 14, 1882.

Barrett, Moses, Milwaukee, Wis. (21). Died in 1873.

Barry, Redmond, Melbourne, Australia (25).

Beck, C. F., Philadelphia, Pa. (1).
Beck, Lewis C., New Brunswick, N. J. (1). Born Oct. 4, 1798. Died April 21, 1853.
Beck, T. Romeyn, Albany, N. Y. (1). Born Aug. 11, 1791. Died Nov. 19, 1855.
Belfrage, G. W., Clifton, Texas (29). Died Dec. 7, 1882.
Belt, Thomas, London, Eng. (27). Died Sept. 8, 1878.
Benedict, George W., Burlington, Vt. (16). Born Jan. 11, 1796. Died in 1871.
Bicknell, Edwin, Boston, Mass. (18). Born in 1830. Died March 19, 1877.
Binney, Amos, Boston, Mass. (1). Born Oct. 18, 1803. Died Feb. 18, 1847.
Binney, John, Boston, Mass. (3).
Blackie, Geo. S., Nashville, Tenn. (26).
Blair, Henry W., Washington, D. C., (26). Died Dec. 15, 1884.
Blake, Homer C., New York, N. Y. (28). Born Feb. 1, 1822.
Blanding, William, ———, R. I. (1).
Blatchford, Thomas W., Troy, N. Y. (6).
Blatchley, Miss S. L., New Haven, Conn. (19). Died March 13, 1873.
Boadle, John, Haddonfield, N. J. (20). Born in 1805. Died in July, 1878.
Bomford, George, Washington, D. C. (1). Born 1780. Died March 25, 1848.
Bowron, James, South Pittsburg, Tenn. (26). Died in Dec., 1877.
Bradley, Leverette, Jersey City, N. J. (15). Died in 1875.
Braithwaite, Jos., Chambly, C. W. (11).
Briggs, Albert D., Springfield, Mass. (13). Died Feb. 20, 1881.
Briggs, Robert, Philadelphia, Pa. (29). Born May 18, 1822. Died July 24, 1882.
Brigham, Charles H., Ann Arbor, Mich. (17). Born July 27, 1820. Died in Jan., 1879.
Brown, Andrew, Natchez, Miss. (1).
Brown, Horace, Salem, Mass. (27). Died in July, 1883.
Bull, John, Washington, D. C. (31). Born Aug. 1, 1819. Died June 9, 1884.
Burbank, L. S., Woburn, Mass. (18).
Burnap, G. W., Baltimore, Md. (12). Born Nov. 30, 1802. Died Sept. 8, 1859.
Burnett, Waldo I., Boston, Mass. (1). Died July 1, 1854, aged 27.
Butler, Thomas B., Norwalk, Conn. (10). Born Aug. 22, 1806. Died June 8, 1878.

Cairns, F. A., New York, N. Y. (27). Died in 1879.
Campbell, Mrs. Mary H., Crawfordsville, Ind. (22). Died Feb. 27, 1882.
Carpenter, Thornton, Camden, S. C. (7).
Carpenter, William M., New Orleans, La. (1).
Case, Leonard, Cleveland, Ohio (15). Born June 27, 1820. Died Jan. 5, 1880.

Case, William, Cleveland, Ohio (6).
Caswell, Alexis, Providence, R. I. (2). Born Jan. 29, 1799. Died Jan. 8, 1877.
Chadbourne, Paul Ansel, Amherst, Mass. (10). Born Oct. 21, 1823. Died Feb. 23, 1883.
Chapman, N., Philadelphia, Pa. (1). Born May 28, 1780. Died July 1, 1853.
Chase, Stephen, Hanover, N. H. (2). Born in 1813. Died Aug. 5, 1851.
Chauvenet, William, St. Louis, Mo. (1). Born May 24, 1819. Died Dec. 13, 1870.
Cheesman, Louis M., Hartford, Conn. (32). Died in Jan. 1885, aged 27 years.
Cheney, Miss Margaret S., Jamaica Plain, Mass. (29).
Clapp, Asahel, New Albany, Ind. (1). Born Oct. 5, 1792. Died Dec. 15, 1862.
Clark, Henry James, Cambridge, Mass. (13). Died July 1, 1873, aged 47.
Clark, Joseph, Cincinnati, Ohio (5).
Clarke, A. B., Holyoke, Mass. (13).
Cleaveland, C. H., Cincinnati, Ohio (9).
Cleveland, A. B., Cambridge, Mass. (2).
Coffin, James H., Easton, Pa. (1). Born Sept. 6, 1806. Died Feb. 6, 1873.
Cole, Thomas, Salem, Mass. (1). Born Dec. 24, 1779. Died June 24, 1852.
Coleman, Henry, Boston, Mass. (1).
Collins, Frederick, Washington, D. C. (28). Born Dec. 5, 1842. Died Oct. 27, 1881.
Conrad, Timothy Abbott, Philadelphia, Pa. (1). Born in August, 1803. Died August 9, 1877.
Cooke, Caleb, Salem, Mass. (18). Born Feb. 15, 1838. Died June 5, 1880.
Cooper, William, Hoboken, N. J. (9). Died in 1864.
Copes, Joseph S., New Orleans, La. (11).
Corning, Erastus, Albany, N. Y. (6). Born Dec. 14, 1794. Died April 9, 1872.
Couper, James Hamilton, Darien, Ga. (1). Born March 5, 1794. Died July 3, 1866.
Cramp, J. M., Wolfville, N. S. (11). Born July 25, 1796. Died Dec. 6, 1881.
Crehore, John D., Cleveland, Ohio (24).
Crocker, Charles F., Lawrence, Mass. (22). Died in July, 1881.
Crosby, Alpheus, Salem, Mass. (10). Born Oct. 13, 1810. Died Apr. 17, 1874.
Crosby, Thomas R., Hanover, N. H. (18). Born Oct. 22, 1816. Died March 1, 1872.
Croswell, Edwin, Albany, N. Y. (6). Born in May, 1797. Died June 13, 1871.
Curry, W. F., Geneva, N. Y. (11).
Curtis, Josiah, Washington, D. C. (18). Died Aug. 1, 1883.

Dalrymple, E. A., Baltimore, Md. (11). Died Oct. 30, 1881.

Dayton, Edwin A., Madrid, N. Y. (7). Born in 1827. Died June 24, 1873.
Dean, Amos, Albany, N. Y. (6). Born Jan. 16, 1803. Died Jan. 26, 1868.
Dearborn, George H. A. S., Roxbury, Mass. (1).
Dekay, James E., New York, N. Y. (1). Born in 1792. Died Nov. 21, 1851.
DeLaski, John, Carver's Harbor, Me. (18).
Dewey, Chester, Rochester, N. Y. (1). Born Oct. 25, 1781. Died Dec. 15, 1867.
Dexter, G. M., Boston, Mass. (11).
Dillingham, W. A. P., Augusta, Me. (17).
Dimmick, L. N., Santa Barbara, Cal. (29). Died May 31, 1884.
Doggett, Mrs. Kate N., Chicago, Ill. (17). Died March 12, 1884.
Doggett, Wm. E., Chicago, Ill. (17). Born Nov. 20, 1820. Died in 1876.
Doolittle, L., Lenoxville, C. E. (11). Died in 1862.
Dorr, E. P., Buffalo, N. Y. (15). Died March 28, 1881.
Draper, Henry, New York, N. Y. (28).
Ducatel, J. T., Baltimore, Md. (1).
Duffield, George, Detroit, Mich. (10). Born July 4, 1794. Died June 26, 1869.
Dumont, A. H., Newport, R. I. (14).
Duncan, Lucius C., New Orleans, La. (10). Died Aug. 9, 1855, aged 54.
Dunn, R. P., Providence, R. I. (14).

Easton, Norman, Fall River, Mass. (14). Died Dec. 21, 1872.
Eaton, James H., Beloit, Wis. (17). Died Jan. 5, 1877.
Elsberg, Louis, New York, N. Y. (23). Died Feb. 19, 1885, aged 48 years.
Elwyn, Alfred L., Philadelphia, Pa. (1). Died March 15, 1884.
Ely, Charles Arthur, Elyria, Ohio (4).
Emerson, Geo. B., Boston, Mass. (1). Born Sept. 12, 1797. Died March 4, 1881.
Emmons, Ebenezer, Williamstown, Mass. (1). Born May 16, 1799. Died October 1, 1863.
Engelmann, George, St. Louis, Mo. (1). Born Feb. 2, 1809. Died Feb. 4, 1884.
Engstrom, A. B., Burlington, N. J. (1).
Eustis, Henry L., Cambridge, Mass. (2). Born Feb. 1, 1819. Died Jan. 11, 1885.
Everett, Edward, Boston, Mass. (2). Born April 11, 1794. Died Jan. 15, 1865.
Ewing, Thomas, Lancaster, Ohio (5). Born Dec. 28, 1789. Died Oct. 26, 1871.

Faries, R. J., Wauwatosa, Wis. (21). Died May 31, 1878.
Farquharson, Robert James, Des Moines, Iowa. (24). Died Sept. 6, 1884.
Ferris, Isaac, New York, N. Y. (6). Born Oct. 9, 1798. Died June 16, 1873.
Feuchtwanger, Lewis, New York, N. Y. (11). Died June 25, 1876.
Fillmore, Millard, Buffalo, N. Y. (7). Born Jan. 7, 1800. Died March 8,
Fisher, Mark, Trenton, N. J. (10). [1874.

Fitch, Alexander, Hartford, Conn. (1). Born March 25, 1799. Died Jan. 20, 1859.
Fitch, O. H., Ashtabula, Ohio (7). Died Sept. 17, 1882, in his 80th year.
Forbush, E. B., Buffalo, N. Y. (15).
Force, Peter, Washington, D. C. (4). Born Nov. 26, 1790. Died Jan. 23, 1868.
Ford, A. C., Nashville, Tenn. (26).
Forshey, Caleb G., New Orleans, La. (21). Died in Aug., 1881.
Foster, John W., Chicago, Ill. (1). Born March 4, 1815. Died June 29, 1873.
Foucon, Felix, Madison, Wis. (18).
Fowle, Wm. B., Boston, Mass. (1). Born Oct. 17, 1795. Died Feb. 6, 1865.
Fox, Charles, Grosse Ile, Mich. (7).
Frazer, John F., Philadelphia, Pa. (1). Born July 8, 1812. Died Oct. 12, 1872.
French, J. W., West Point, N. Y. (11).

Garber, A. P., Columbia, Pa. (29). Died Aug. 26, 1881.
Gavit, John E., New York, N. Y. (1).
Gay, Martin, Boston, Mass. (1). Died Jan. 12, 1850, aged 46.
Gibbon, J. H., Charlotte, N. C. (3).
Gillespie, W. M., Schenectady, N. Y. (10). Born in 1816. Died Jan'y 1, 1868.
Gilmor, Robert, Baltimore, Md. (1).
Glazier, W. W., Key West, Fla. (29). Died Dec. 11, 1880.
Goldmark, J., New York, N. Y. (29). Died in April, 1882.
Gould, Augustus A., Boston, Mass. (11). Born April 23, 1805. Died Sept. 15, 1866.
Gould, B. A., Boston, Mass. (2). Born June 15, 1787. Died Oct. 24, 1859.
Graham, James D., Washington, D. C. (1). Born in 1799. Died Dec. 28, 1865.
Gray, Alonzo, Brooklyn, N. Y. (13). Born in 1808. Died March 10, 1860.
Gray, James H., Springfield, Mass. (6).
Greene, Benjamin D., Boston, Mass. (1). Died Oct. 14, 1862, aged 68.
Greene, Everett W., Madison, N. J. (10). Died in 1864.
Greene, Samuel, Woonsocket, R. I. (9). Died in 1868.
Greer, James, Dayton, Ohio (20). Died in Feb., 1874.
Griffith, Robert E., Philadelphia, Pa. (1).
Griswold, John A., Troy, N. Y. (19). Born in 1822. Died Oct. 31, 1872.
Guest, William E., Ogdensburg, N. Y. (6).
Guyot, Arnold, Princeton, N. J. (1). Born Sept. 5, 1809. Died Feb. 8, 1884.

Hackley, Charles W., New York, N. Y. (4). Born March 9, 1809. Died January 10, 1861.
Hadley, George, Buffalo, N. Y. (6). Born June, 1813. Died Oct. 16, 1877.

Haldeman, S. S., Chickies, Pa. (1). Died Sept. 10, 1880, aged 68.
Hale, Enoch, Boston, Mass. (1). Born Jan. 29, 1790. Died Nov. 12, 1848.
Hance, Ebenezer, Fallsington P. O., Pa. (7). Died in 1876.
Hare, Robert, Philadelphia, Pa. (1). Born Jan. 17, 1781. Died May 15, 1858.
Harlan, Joseph G., Haverford, Pa. (8).
Harlan, Richard, Philadelphia, Pa. (1).
Harris, Thaddeus W., Cambridge, Mass. (1). Born Nov. 12, 1795. Died Jan. 16, 1856.
Harrison, A. M., Plymouth, Mass. (29).
Harrison, Jos., jr., Philadelphia, Pa. (12).
Hart, Simeon, Farmington, Conn. (1). Died April 20, 1853, aged 57.
Hartt, Charles F., Ithaca, N. Y. (18). Born in 1840. Died March 18, 1878.
Haven, Joseph, Chicago, Ill. (17). Born Jan. 4, 1816. Died May 23, 1874.
Hawes, George W., Washington, D. C. (23). Born Dec. 31, 1848. Died June 22, 1882.
Hayden, H. H., Baltimore, Md. (1).
Hayes, George E., Buffalo, N. Y. (15).
Hayward, James, Boston, Mass. (1). Died July 27, 1866, aged 80.
Hempstead, G. S. B., Portsmouth, Ohio (29). Died July 9, 1883, in his 89th year.
Henry, Jos., Washington, D. C. (1). Born Dec. 17, 1797. Died May 13, 1878.
Hickox, S. V. R., Chicago, Ill. (17). Died in 1872.
Hilgard, Theo. C., St. Louis, Mo. (17). Born Feb. 28, 1828. Died Mch. 5, 1875.
Hill, Walter N., Chester, Pa. (29). Born April 15, 1846. Died March 29, 1884.
Hincks, William, Toronto, C. W. (11).
Hitchcock, Edward, Amherst, Mass. (1). Born May 24, 1793. Died Feb. 27, 1864.
Hodgson, W. B., Savannah, Ga. (10). Born 1815.
Holbrook, John E., Charleston, S. C. (1). Born Dec. 31, 1796. Died Sept. 8, 1871.
Hopkins, Albert, Williamstown, Mass. (19). Born July 14, 1807. Died May 25, 1872.
Hopkins, James G., Ogdensburg, N. Y. (10). Died in 1860.
Hopkins, T. O., Williamsville, N. Y. (10). Died in 1866.
Hopkins, Wm., Lima, N. Y. (5.) Died in March, 1867.
Horton, C. V. R., Chaumont, N. Y. (10). Died in 1862.
Horton, William, Craigville, N. Y. (1).
Hosford, Benj. F., Haverhill, Mass. (13). Died in 1864.
Houghton, Douglas, Detroit, Mich. (1). Born Sept. 21, 1809. Died Oct. 13, 1845.
Hovey, Edmund O., Crawfordsville, Ind. (20). Born July 15, 1801. Died March 10, 1877.
Howland, Theodore, Buffalo, N. Y. (15).
Hubbert, James, Richmond, Province of Quebec (16). Died in 1868.

Hunt, Edward B., Washington, D. C. (2). Born June 15, 1822. Died Oct. 2, 1863.
Hunt, Freeman, New York, N. Y. (11). Born March 21, 1804. Died March 2, 1858.

Ives, Moses B., Providence, R. I. (9). Died in 1857.
Ives, Thomas P., Providence, R. I. (10).

Jackson, Charles T., Boston, Mass. (1). Born June 21, 1805. Died Aug. 29, 1880.
James, Thomas Potts, Cambridge, Mass. (22). Born Sept. 1, 1803. Died Feb. 22, 1882.
Johnson, Walter R., Washington, D. C. (1). Born June 21, 1794. Died April 26, 1852.
Johnson, William Schuyler, Washington, D. C. (31). Born Sept. 20, 1859. Died Oct. 6, 1883.
Jones, Catesby A. R., Washington, D. C. (8).
Jones, Henry A., Portland, Me. (29). Died Sept. 3, 1883.
Jones, James H., Boston, Mass. (28).

Kedzie, W. K., Oberlin, Ohio (25).
Keely, George W., Waterville, Me. (1). Died in 1878.
Keep, N. C., Boston, Mass. (13). Died in March, 1875.
Kennicott, Robert, West Northfield, Ill. (12). Born Nov. 13, 1835. Died in 1866.
King, Mitchell, Charleston, S. C. (3). Born June 8, 1783. Died in 1862.
Kite, Thomas, Cincinnati, Ohio (5). Died Feb. 6, 1884.
Klippart, John H., Columbus, Ohio (17). Died October, 1878.
Knickerbocker, Charles, Chicago, Ill. (17). Died in 1873.
Knight, J. B., Philadelphia, Pa. (21). Died March 10, 1879.

Lacklan, R., Cincinnati, Ohio (11).
Lapham, Increase A., Milwaukee, Wis. (3). Born Mch. 7, 1811. Died Sept. 14, 1875.
LaRoche, R., Philadelphia, Pa. (12).
Lasel, Edward, Williamstown, Mass. (1). Born Jan. 21, 1809. Died in 1852.
Lawford, Frederick, Montreal, Canada (11). Died in 1866.
Le Conte, John L., Philadelphia, Pa. (1). Died Nov. 15, 1883.
Lederer, Baron von, Washington, D. C. (1).
Lieber, Oscar M., Columbia, S. C. (3). Born Sept. 8, 1830. Died June 27, 1862.
Lincklaen, Ledyard, Cazenovia, N. Y. (1).
Linsley, James H., Stafford, Conn. (1). Born May 5, 1787. Died Dec. 26, 1843.

Lockwood, Moses B., Providence, R. I. (9). Died in 1872.
Logan, William E., Montreal, Canada (1). Born April 28, 1798. Died June 22, 1875.
Loosey, Charles F., New York, N. Y. (12).
Lothrop, Joshua R., Buffalo, N. Y. (15).
Lyon, Sidney S., Jeffersonville, Ind. (20). Born Aug. 4, 1806. Died June 24, 1872.

Maack, G. A., Cambridge, Mass. (18). Died in Aug., 1875.
Mahan, Dennis H., West Point, N. Y. (9). Born April 2, 1802. Died Sept. 16, 1871.
Marsh, Dexter, Greenfield, Mass. (1).
Marsh, James E., Roxbury, Mass. (10).
Martin, B. N., New York, N. Y. (23). Died Dec. 26, 1883.
Mather, William W., Columbus, Ohio (1). Born May 24, 1804. Died Feb. 27, 1859.
Maude, John B., St. Louis, Mo. (27). Died in April, 1879.
Maupin, S., Charlottesville, Va. (10).
M'Conihe, Isaac, Troy, N. Y. (5).
McFadden, Thomas, Westerville, Ohio (30). Born Nov. 9, 1825. Died Nov. 9, 1883.
McMahon, Mathew, Albany, N. Y. (11).
Meade, George G., Philadelphia, Pa. (15). Born Dec. 30, 1815. Died Nov. 6, 1872.
Meek, F. B., Washington, D. C. (6). Born December 10, 1817. Died December 21, 1876.
Meigs, James Aitken, Philadelphia, Pa. (12). Born July 30, 1829. Died Nov. 9, 1879.
Minifie, William, Baltimore, Md. (12). Born in 1805. Died Oct. 24, 1880.
Mitchel, O. M., Cincinnati, Ohio (3). Born Aug. 28, 1810. Died Oct. 30, 1862.
Mitchell, William, Poughkeepsie, N. Y. (2). Died April 2, 1869, aged 76.
Mitchell, Wm. H., Florence, Ala. (17).
Morgan, Lewis H., Rochester, N. Y. (10). Born Nov. 21, 1818. Died Dec. 17, 1881.
Morgan, Mrs. Mary E., Rochester, N. Y. (31).
Morris, John B., Nashville, Tenn. (26).
Morton, Samuel G., Philadelphia, Pa. (1). Born Jan. 26, 1799. Died May 15, 1851.
Mudge, Benjamin F., Manhattan, Kansas (25). Born Aug. 11, 1817. Died Nov. 21, 1879, aged 62.
Monroe, Nathan, Bradford, Mass. (6). Born May 16, 1804. Died July 8, 1866.
Monroe, William, Concord, Mass. (18). Died April 27, 1877.
Mussey, William H., Cincinnati, Ohio (30). Born Sept. 13, 1818. Died Aug. 1, 1882.

Newland, John, Saratoga Springs, N. Y. (28). Died Jan. 18, 1880.
Newton, E. H., Cambridge, N. Y. (1).
Nichols, Charles A., Providence, R. I. (17). Born Jan. 4, 1826. Died Oct. 20, 1877.
Nicholson, Thomas, New Orleans, La. (21).
Nicollett, Jean N., Washington, D. C. (1). Born July 24, 1786. Died Sept. 11, 1843.
Norton, John P., New Haven, Conn. (1). Born in July, 1822. Died Sept. 5, 1852.
Norton, W. A., New Haven, Conn. (6).
Noyes, J. O., New Orleans, La. (21).
Nutt, Cyrus, Bloomington, Ind. (20). Died in 1875.

Oakes, Wm., Ipswich, Mass. (1). Born July 1, 1799. Died July 31, 1848.
Ogden, Robert W., New Orleans, La. (21). Died March 24, 1878.
Ogden, William B., High Bridge, Westchester Co., N. Y. (17). Born in 1805. Died Aug. 3, 1877.
Olmsted, Alexander F., New Haven, Conn. (4). Born Dec. 20, 1822. Died May 5, 1853.
Olmsted, Denison, New Haven, Conn. (1). Born June 18, 1791. Died May 13, 1859.
Olmsted, Denison, jr., New Haven, Conn. (1). Born Feb. 16, 1824. Died Aug. 15, 1846.
Orton, James, Poughkeepsie, N. Y. (18). Died Sept. 24, 1877.
Osbun, Isaac J., Salem, Mass. (29).
Otis, George Alexander, Washington, D. C. (10). Born Nov. 12, 1830. Died Feb. 23, 1881.

Packer, Harry E., Mauch Chunk, Pa. (30). Died Feb. 1, 1884.
Painter, Jacob, Lima, Pa. (23). Died in 1876.
Painter, Minshall, Lima, Pa. (7).
Parker, Wilbur F., West Meriden, Conn. (23). Died in 1876.
Parkman, Samuel, Boston, Mass. (1). Died Dec. 15, 1854, aged 38.
Payn, Charles H., Saratoga Springs, N. Y. (28). Born May 16, 1814. Died Dec. 20, 1881.
Peirce, B. O., Beverly, Mass. (18). Died Nov. 12, 1883, aged 71 years.
Peirce, Benjamin, Cambridge, Mass. (1). Born April 4, 1809. Died Oct. 6, 1880.
Perkins, George R., Utica, N. Y. (1). Born May 3, 1812. Died Aug. 22, 1876.
Perkins, Henry C., Newburyport, Mass. (18). Born Nov. 13, 1804. Died Feb. 2, 1873.
Perry, John B., Cambridge, Mass. (16). Died Oct. 3, 1872, aged 52.
Perry, M. C., New York, N. Y. (10).

Phelps, Mrs. Almira Hart Lincoln, Baltimore, Md. (13). Died July 15, 1884, in her 91st year.
Phillips, John C., Boston, Mass. (29). Died March 1, 1885, aged 46 yrs. 9 mos.
Piggot, A. Snowden, Baltimore, Md. (10).
Plumb, Ovid, Salisbury, Conn. (9).
Pope, Charles A., St. Louis, Mo. (12). Born May 15, 1818. Died July 6, 1870.
Porter, John A., New Haven, Conn. (14). Born March 15, 1822. Died Aug. 25, 1866.
Potter, Stephen H., Hamilton, Ohio (30). Born Nov. 10, 1812. Died Dec. 9, 1883.
Pourtalès, Louis François de, Cambridge, Mass. (1). Born in 1822. Died July 18, 1880.
Pruyn, John V. L., Albany, N. Y. (1). Born June 22, 1811. Died Nov. 21, 1877.
Pugh, Evan, Centre Co., Pa. (14).
Pulsifer, Sidney, Philadelphia, Pa. (21). Died March 24, 1884.
Putnam, Mrs. F. W., Cambridge, Mass. (19). Born Dec. 29, 1838. Died March 10, 1879.
Putnam, J. Duncan, Davenport, Iowa (27). Born Oct. 18, 1855. Died Dec. 10, 1881.

Read, Ezra, Terre Haute, Ind. (20). Died in 1877.
Redfield, William C., New York (1). Born March 26, 1789. Died Feb. 12, 1857.
Resor, Jacob, Cincinnati, Ohio (8). Died in 1871.
Robb, James, Fredericton, N. B. (4).
Robinson, Coleman T., Buffalo, N. Y. (15).
Rockwell, John A., Norwich, Conn. (10). Born August 27, 1803. Died February 10, 1861.
Rogers, Henry D., Glasgow, Scotland (1). Born 1809. Died May 29, 1866.
Rogers, James B., Philadelphia, Pa. (1). Born February 22, 1803. Died June 15, 1852.
Rogers, Robert E., Philadelphia, Pa. (18). Died Sept. 7, 1884.
Rogers, William Barton, Boston, Mass. (1). Born Dec. 7, 1804. Died May 30, 1882.
Root, Elihu, Amherst, Mass. (25). Born Sept. 14, 1845.

Sager, Abram, Ann Arbor, Mich. (6). Born December 22, 1810. Died August 6, 1877.
Sanders, Benjamin D., Wellsburg, W. Va. (19).
Schaeffer, Geo. C., Washington, D. C. (1). Died in 1873.
Schley, William, New York, N. Y. (28). Died in 1882.
Scott, Joseph, Dunham, C. E. (11). Died in 1865.
Seaman, Ezra C. (20).

Senter, Harvey S., Aledo, Ill. (20). Died in 1875.
Seward, William H., Auburn, N. Y. (1). Born May 16, 1801. Died Oct. 10, 1872.
Sheppard, William, Drummondville, Province of Quebec, Can. (11). Born in 1783. Died in 1867.
Sherwin, Thomas, Dedham, Mass. (11). Born March 26, 1799. Died July 23, 1869.
Silliman, Benjamin, New Haven, Conn. (1). Born August 8, 1779. Died November 22, 1864.
Silliman, Benjamin, New Haven, Conn. (1). Born Dec. 4, 1816. Died Jan. 14, 1885.
Skinner, John B., Buffalo, N. Y. (15). Died in 1871.
Slack, J. H., Philadelphia, Pa. (12).
Smith, Charles A., St. Louis, Mo. (27). Died in 1884.
Smith, David P., Springfield, Mass. (29). Born Oct. 1, 1830. Died Dec. 26, 1880.
Smith, J. Lawrence, Louisville, Ky. (1). Born Dec. 16, 1818. Died Oct. 12, 1883.
Smith, J. V., Cincinnati, Ohio (5).
Smith, James Y., Providence, R. I. (9). Born September 15, 1809. Died in 1876.
Smith, Lyndon A., Newark, N. J. (9). Born November 11, 1795. Died December 15, 1865.
Snell, Ebenezer S., Amherst, Mass. (2). Born October 7, 1801. Died in September, 1877.
Sparks, Jared, Cambridge, Mass. (2). Born May 10, 1789. Died March 14, 1866.
Spinzig, Charles, St. Louis, Mo. (27). Died Jan. 22, 1882.
Stearns, Josiah A., Boston, Mass. (29).
Stimpson, William, Chicago, Ill. (12). Died May 26, 1872.
Stone, Samuel, Chicago, Ill. (17). Born Dec. 6, 1798. Died May 4, 1876.
St. John, Joseph S., Albany, N. Y. (28). Died Nov. 23, 1882.
Sullivant, William S., Columbus, Ohio (7). Born Jan. 15, 1803. Died April 30, 1873.
Swain, James, Fort Dodge, Iowa (21). Born in 1816. Died in 1877.

Tallmadge, James, New York, N. Y. (1). Born Jan. 20, 1778. Died Oct. 3, 1853.
Taylor, Arthur F., Cleveland, Ohio (29). Born Dec. 10, 1853. Died June 28, 1883.
Taylor, Richard C., Philadelphia, Pa. (1). Born January 18, 1789. Died November 26, 1851.
Tenney, Sanborn, Williamstown, Mass. (17). Born in January, 1827. Died July 11, 1877.
Teschemacher, J. E., Boston, Mass. (1). Died Nov. 9, 1853, aged 63.
Thompson, A. Remsen, New York, N. Y. (1). Died in Oct., 1879.
Thompson, Alexander, Aurora, N. Y. (1).

Thompson, Zadock, Burlington, Vt. (1). Born May 23, 1796. Died Jan. 19, 1856.
Thurber, Isaac, Providence, R. I. (9).
Tillman, Samuel D., Jersey City, N. J. (15). Died in 1875.
Tobin, Thomas W., Louisville, Ky. (30). Died Aug. 4, 1883.
Tolderoy, James B., Fredericton, N. B. (11).
Torrey, John, New York, N. Y. (1). Born Aug. 15, 1796. Died March 10, 1873.
Torrey, Joseph, Burlington, Vt. (2). Born Feb. 2, 1797. Died Nov. 26, 1867.
Totten, Joseph G., Washington, D. C. (1). Born August 23, 1788. Died April 22, 1864.
Townsend, Howard, Albany, N. Y. (10). Died in 1867.
Townsend, John K., Philadelphia, Pa. (1).
Townsend, Robert, Albany, N. Y. (9). Died in 1866.
Troost, Gerard, Nashville, Tenn. (1). Born March 15, 1776. Died Aug. 14, 1850.
Tuomey, Michael, Tuscaloosa, Ala. (1). Born September 29, 1805. Died March 20, 1857.
Tyler, Edward R., New Haven, Conn. (1). Died Sept. 28, 1848.

Vancleve, John W., Dayton, Ohio (1).
Vanuxem, Lardner, Bristol, Pa. (1).
Vaux, William S., Philadelphia, Pa. (1). Born May 19, 1811. Died May 5, 1882.

Wadsworth, James S., Genesee, N. Y. (2). Born October 30, 1807. Died May 8, 1864.
Wagner, Tobias, Philadelphia, Pa. (9).
Walker, Joseph, Oxford, N. Y. (10).
Walker, Sears C., Washington, D. C. (1). Born March 28, 1805. Died January 30, 1853.
Walker, Timothy, Cincinnati, Ohio (4). Born Dec. 1, 1802. Died Jan. 15, 1856.
Walsh, Benjamin D., Rock Island, Ill. (17).
Wanzer, Ira, Brookfield, Conn. (18). Born April 17, 1796. Died March 5, 1879.
Warren, Gouverneur Kemble, Newport, R. I. (12). Died Aug. 8, 1882, in his 64th year.
Warren, John C., Boston, Mass. (1). Born Aug. 1, 1778. Died May 4, 1856.
Watertown, Charles, Wakefield, Eng. (1).
Watkins, Samuel, Nashville, Tenn. (26).
Watson, J. Craig, Ann Arbor, Mich. (13). Born Jan. 28, 1838. Died Nov. 23, 1880.
Webster, Horace B., Albany, N. Y. (1). Died Dec. 8, 1843.

Webster, J. W., Cambridge, Mass. (1). Died Aug. 30, 1850, aged 57.
Webster, M. H., Albany, N. Y. (1).
Weed, Monroe, Wyoming, N. Y. (6). Died in 1867.
Welch, Mrs. G. O., Lynn, Mass. (21). Died in June, 1882.
Weyman, George W., Pittsburg, Pa. (6). Born April, 1832. Died July 16, 1864.
Wheatland, Richard H., Salem, Mass. (13). Born July 6, 1830. Died Dec. 21, 1863.
Wheatley, Charles M., Phœnixville, Pa. (1). Died May 6, 1882.
Wheeler, Arthur W., Baltimore, Md. (29). Born in March, 1859. Died Jan. 6, 1881.
White, Samuel S., Philadelphia, Pa. (23). Died Dec. 30, 1879.
Whiting, Lewis E., Saratoga Springs, N. Y. (28). Born March 7, 1815. Died Aug. 2, 1882.
Whitman, Wm. E., Philadelphia, Pa. (23). Died in 1875.
Whitney, Asa, Philadelphia, Pa. (1). Born Dec. 1, 1791. Died June 4, 1874.
Whittlesey, Charles C., St. Louis, Mo. (11). Died in 1872.
Willard, Emma, Troy, N. Y. (15). Born Feb. 23, 1787. Died April 15, 1870.
Williamson, R. S., San Francisco, Cal. (12).
Wilson, W. C., Carlisle, Pa. (12).
Winlock, Joseph, Cambridge, Mass. (5). Born Feb. 6, 1826. Died June 11, 1875.
Woodbury, Levi, Portsmouth, N. H. (1). Born Dec. 22, 1789. Died Sept. 4, 1851.
Woodman, John S., Hanover, N. H. (11). Born in 1819. Died May 15, 1871.
Woodward, J. J., Washington, D. C. (28).
Wright, John, Troy, N. Y. (1).
Wyman, Jeffries, Cambridge, Mass. (1). Born Aug. 11, 1814. Died Sept. 4, 1874.

Yarnall, M., Washington, D. C. (26). Born in 1817. Died Jan. 27, 1879.
Young, Ira, Hanover, N. H. (1). Died Sept. 14, 1858, aged 57.

# ADDRESS

BY

# PROFESSOR C. A. YOUNG,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

## *PENDING PROBLEMS IN ASTRONOMY.*

MR. PRESIDENT, LADIES AND GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: —

THIRTY-SIX years ago this very month, in this city, and near the place where we are now assembled, the American Association for the Advancement of Science was organized, and held its first meeting. Now, for the first time, it revisits its honored birthplace.

Few of those present this evening were, I suppose, in attendance upon that first meeting. Here and there, among the members of the association, I see, indeed, the venerable faces of one and another, who, at that time in the flush and vigor of early manhood, participated in its proceedings and discussions; and there are others, who, as boys or youths, looked on in silence, and listening to the words of Agassiz and Peirce, of Bache and Henry, and the Rogers brothers and their associates, drank in that inspiring love of truth and science which ever since has guided and impelled their lives. Probably enough, too, there may be among our hosts in the audience a few who remember that occasion, and were present as spectators.

But, substantially, we who meet here to-day are a new generation, more numerous certainly, and in some respects unquestionably better equipped for our work, than our predecessors were; though we might not care to challenge comparisons as regards native ability, or clearness of insight, or lofty purpose.

And the face of science has greatly changed in the meantime; as much, perhaps, as have this great city and the nation. One might almost say, that, since 1848, "all things have become new" in the

scientific world. There is a new mathematics and a new astronomy, a new chemistry and a new electricity, a new geology and a new biology. Great voices have spoken, and have transformed the world of thought and research as much as the material products of science have altered the aspects of external life. The telegraph and dynamo-machine have not more changed the conditions of business and industry than the speculations of Darwin and Helmholtz and their compeers have affected those of philosophy and science.

But, although this return to our birthplace suggests retrospections and comparisons which might profitably occupy our attention for even a much longer time than this evening's session, I prefer, on the whole, to take a different course; looking forwards rather than backwards, and confining myself mainly to topics which lie along my own line of work.

The voyager, upon the inland sea of Japan, sees continually rising before him new islands and mountains of that fairyland. Some come out suddenly from behind nearer rocks or islets, which long concealed the greater things beyond; and some are veiled in clouds which give no hint of what they hide, until a breeze rolls back the curtain: some, and the greatest of them all, are first seen as the minutest speck upon the horizon, and grow slowly to their final grandeur. Even before they reach the horizon line, while yet invisible, they sometimes intimate their presence by signs in sky and air; so slight, indeed, that only the practised eye of the skilful sailor can detect them, though quite obvious to him.

Somewhat so, as we look forward into the future of a science, we see new problems and great subjects presenting themselves. Some are imminent and in the way, — they must be dealt with at once, before further progress can be made; others are more remotely interesting in various degrees; and some, as yet, are mere suggestions, almost too misty and remote for steady contemplation.

With your permission, I propose this evening to consider some of the pending problems of astronomy, — those which seem to be most pressing and most urgently require solution as a condition of advance, and those which appear most interesting or easy to be attacked from a philosophic point of view.

[illegible]

I think the impression prevails, that we already know the earth's dimensions with an accuracy even greater than that required by any astronomical demands. I certainly had that impression myself not long ago, and was a little startled on being told by the superintendent of our Nautical almanac that the remaining uncertainty is still sufficient to produce serious embarrassment in the reduction and comparison of certain lunar observations. The length of the line joining, say, the Naval observatory at Washington with the Royal observatory at Cape of Good Hope, is doubtful; not to the extent of only a few hundred feet, as commonly supposed, but the uncertainty amounts to some thousands of feet, and may possibly be a mile or more — probably not less than a ten-thousandth of the whole distance; and the *direction* of the line is uncertain in about the same degree. Of course, on those portions of either continent which have been directly connected with each other by geodetic triangulations, no corresponding uncertainty obtains; and as time goes on, and these surveys are extended, the form and dimensions of each continuous land-surface will become more and more perfectly determined. But at present we have no satisfactory means of obtaining the desired accuracy in the relative position of places separated by oceans, so that they cannot be connected by chains of triangulation. Astronomical determinations of latitude and longitude do not meet the case; since, in the last analysis, they only give at any selected station the *direction of gravity* relative to the axis of the earth and some fixed meridian plane, and do not furnish any linear measurement or dimension.

Of course, if the surface of the earth were an exact spheroid, and if there were no irregular attractions due to mountains and valleys and the varying density of strata, the difficulty could be easily evaded; but, as the matter stands, it looks as if nothing short of a complete geodetic triangulation of the whole earth would ever answer the purpose, — a triangulation covering Asia and Africa, as well as Europe, and brought into America by the way of Siberia and Behring's Strait.

It is indeed theoretically possible, and just conceivable, that the problem may some day be reversed, and that the geodesist may come to owe some of his most important data to the observers of the lunar motions. When the relative position of two or more remote observatories shall have been precisely determined by triangulation (for instance, Greenwich, Madras, and the Cape of Good

Hope), and when, by improved methods and observations made at these fundamental stations, the moon's position and motion relative to them shall have been determined with an accuracy much exceeding anything now attainable, then by similar observations, made simultaneously at any station in this hemisphere, it will be theoretically possible to determine the position of this station, and so, by the way of the moon, to bridge the ocean, and ascertain how other stations are related to those which were taken as primary. I do not, of course, mean to imply, that, in the present state of observational astronomy, any such procedure would lead to results of much value; but, before the Asiatic triangulation meets the American at Behring's Strait, it is not unlikely that the accuracy of lunar observations will be greatly increased.

The present uncertainty as to the earth's dimensions is not, however, a sensible embarrassment to astronomers, except in dealing with the moon; especially in attempting to employ observations made at remote and ocean-separated stations for the determination of her parallax.

As to the form of the earth, it seems pretty evident that before long it will be wise to give up further attempts to determine exactly what spheroid or ellipsoid *most nearly corresponds* to the actual figure of the earth; since every new continental survey will require a modification of the elements of this spheroid in order to take account of the new data. It will be better to assume some closely approximate spheroid as a finality; its elements to be forever retained unchanged, while the deviations of the actual surface from this ideal standard will be the subject of continued investigation and measurement.

A more important and anxious question of the modern astronomer is this, Is the earth's rotation uniform, and, if not, in what way and to what extent does it vary? The importance, of course, lies in the fact that this rotation furnishes our fundamental measure and unit of time.

Up to a comparatively recent date, there has not been reason to suspect this unit of any variation sufficient to be detected by human observation. It has long been perceived, of course, that any changes in the earth's form or dimensions must alter the length of the day. The displacement of the surface or strata by earthquakes or by more gradual elevation and subsidence, the transportation of matter towards or from the equator by rivers or

ocean currents, the accumulation or removal of ice in the polar regions or on mountain-tops, — any such causes must necessarily produce a real effect. So, also, must the friction of tides and trade-winds. But it has been supposed that these effects were so minute, and to such an extent mutually compensatory, as to be quite beyond the reach of observation; nor is it yet certain that they are not. All that can be said is, that it is now beginning to be *questionable* whether they are, or are not.

The reason for suspecting perceptible variation in the earth's revolution lies mainly in certain unexplained irregularities in the apparent motions of the moon. She alone, of all the heavenly bodies, changes her place in the sky so rapidly, that minute inaccuracies of a second or two in the time of observation would lead to sensible discrepancies in the observed position; an error of one second, in the time, corresponding to about half a second in her place, — a quantity minute, certainly, but perfectly observable. No other heavenly body has an apparent movement anywhere nearly as rapid, excepting only the inner satellite of Mars; and this body is so minute that its accurate observation is impracticable, except with the largest telescopes, and at the times when Mars is unusually near the earth.

Now, of late, the motions of the moon have been very carefully investigated, both theoretically and observationally; and, in spite of everything, there remain discrepancies which defy explanation. We are compelled to admit one of three things, — either the lunar theory is in some degree mathematically incomplete, and fails to represent accurately the gravitational action of the earth and sun, and other known heavenly bodies, upon her movements; or some unknown force other than the gravitational attractions of these bodies is operating in the case; or else, finally, the earth's rotational motion is more or less irregular, and so affects the time-reckoning, and confounds prediction.

If the last is really the case, it is in some sense a most discouraging fact, necessarily putting a limit to the accuracy of all prediction, unless some other unchanging and convenient measure of time shall be found to replace the "day" and "second."

The question at once presents itself, How can the constancy of the day be tested? The lunar motions furnish grounds of suspicion, but nothing more; since it is at least likely that the math-

ematical theory is minutely incorrect or incomplete as that the day is sensibly variable.

Up to the present time, the most effective tests suggested are from the transits of Mercury and from the eclipses of Jupiter's satellites. On the whole, the result of Professor Newcomb's elaborate and exhaustive investigation of all the observed transits, together with all the available eclipses and occultations of stars, tends rather to establish the sensible constancy of the day, and to make it pretty certain (to use his own language) that "inequalities in the lunar motions, not accounted for by the theory of gravitation, really exist, and in such a way that the mean motion of the moon between 1800 and 1875 was really less (*i.e.*, slower) than between 1720 and 1800." Until lately, the observations of Jupiter's satellites have not been made with sufficient accuracy to be of any use in settling so delicate a question; but at present the observation of their eclipses is being carried on at Cambridge, Mass., and elsewhere, by methods that promise a great increase of accuracy over anything preceding. Of course, no *speedy* solution of the problem is possible through such observations, and their result will not be so free from mathematical complications as desirable, — complications arising from the mutual action of the satellites, and the ellipsoidal form of the planet. On account of its freedom from all sensible disturbances, the remote and solitary satellite of Neptune may possibly some time contribute useful data to the problem.

We have not time, and it lies outside my present scope, to discuss, whether, and, if so, how, it may be possible to find units of time and length which shall be independent of the earth's conditions and dimensions; free from all *local considerations*, cosmical, and as applicable in the planetary system of the remotest star as in our own. At present we can postpone its consideration; but the time must unquestionably come, when the accuracy of scientific observation will be so far increased, that the irregularities of the earth's rotation, produced by the causes alluded to a few minutes ago, will protrude, and become intolerable. Then a new unit of time will have to be found for scientific purposes, founded, perhaps, as has been already suggested by many physicists, upon the vibrations or motion of light, or upon some other physical action which pervades the universe.

Another problem of terrestrial astronomy relates to the constancy of the position of the earth's axis in the globe. Just as displacements of matter upon the surface or in the interior of the earth would produce changes in the time of rotation, so also would they cause corresponding alterations in the position of the axis and in the places of the poles, — changes certainly very minute. The only question is, whether they are so minute as to defy detection. It is easy to see that any such displacements of the earth's axis will be indicated by changes in the *latitudes* of our observatories. If, for instance, the pole were moved a hundred feet from its present position towards the continent of Europe, the latitudes of European observatories would be increased about one second, while in Asia and America the effects would be trifling.

The only observational evidence of such movements of the pole, which thus far amounts to anything, is found in the results obtained by Nyren in reducing the determinations of the latitude of Pulkowa, made with the great vertical circle, during the last twenty-five years. They seem to show a slow, steady diminution of the latitude of this observatory, amounting to about a second in a century; as if the north pole were drifting away, and increasing its distance from Pulkowa at the rate of about one foot a year. The Greenwich and Paris observations do not show any such result; but they are not conclusive, on account of the difference of longitude, to say nothing of their inferior precision. The question is certainly a doubtful one; but it is considered of so much importance, that, at the meeting of the International geodetic association in Rome last year, a resolution was adopted recommending observations specially designed to settle it. The plan of Sig. Fergola, who introduced the resolution, is to select pairs of stations, having nearly the same latitude, but differing widely in longitude, and to determine the *difference* of their latitudes by observations of the same set of stars, observed with similar instruments, in the same manner, and reduced by the same methods and formulæ. So far as possible, the same observers are to be retained through a series of years, and are frequently to exchange stations when practicable, so as to eliminate personal equations. The main difficulty of the problem lies, of course, in the minuteness of the effect to be detected; and the only hope of success lies in the most scrupulous care and precision in all the operations involved.

Other problems, relating to the rigidity of the earth and its in-

ternal constitution and temperature, have, indeed, astronomical bearings, and may be reached to some extent by astronomical methods and considerations; but they lie on the border of our science, and time forbids anything more than their mere mention here.

If we consider, next, the problems set us by the moon, we find them numerous, important and difficult. A portion of them are purely mathematical, relating to her orbital motion; while others are physical, and have to do with her surface, atmosphere, heat, etc.

As has already been intimated, the lunar theory is not in a satisfactory state. I do not mean, of course, that the moon's deviations from the predicted path are gross and palpable,—such, for instance as could be perceived by the unaided eye (this I say for the benefit of those who otherwise might not understand how small a matter sets astronomers to grumbling); but they are large enough to be easily observable, and even obtrusive, amounting to several seconds of arc, or miles of space. As we have seen, the attempt to account for them by the irregularity of the earth's rotation has apparently failed; and we are driven to the conclusion, either that other forces than gravitation are operative upon the lunar motions, or else (what is far more probable, considering the past history of theoretical astronomy) that the mathematical theory is somewhere at fault.

To one looking at the matter a little from the outside, it seems as if that which is most needed just now, in order to secure the advance of science in many directions, is a new, more comprehensive, and more manageable solution of the fundamental equations of motion under attraction. Far be it from me to cry out against those mathematicians who delight themselves in transcendental and $n$-dimensional space, and revel in the theory of numbers,—we all know how unexpectedly discoveries and new ideas belonging to one field of science find use and application in widely differing regions,—but I own, I feel much more interest in the study of the theory of functions and differential equations, and expect more aid for astronomy from it.

The problem of any number of bodies, moving under their mutual attraction, according to the Newtonian laws, stands, from a physical point of view, on precisely the same footing as that of *two*

bodies. Given the masses, and the positions and velocities corresponding to any moment of time, then the whole configuration of the system for all time, past and future (abstracting outside forces, of course), is absolutely determinate, and amenable to calculation. But while, in the case of *two* bodies, the calculation is easy and feasible by methods known for two hundred years, our analysis has not yet mastered the general problem for more than two. In special instances, by computations, tedious, indirect, and approximate, we can, indeed, carry our predictions forward over long periods, or indicate past conditions with any required degree of accuracy; but a general and universally practicable solution is yet wanting. The difficulties in the way are purely mathematical: a step needs to be taken, corresponding in importance to the introduction of the circular functions into trigonometry, the invention of logarithms, or the discovery of the calculus. The problem confronts the astronomer on a hundred different roads; and, until it is overcome, progress in these directions must be slow and painful. One could not truly say, perhaps, that the lunar theory must, in the meanwhile, remain quite at a standstill: labor expended in the old ways, upon the extension and development of existing methods, may not be fruitless, and may, perhaps, after a while, effect the reconcilement of prediction and observation far beyond the present limits of accuracy. But if we only had the mathematical powers we long for, then progress would be as by wings: we should fly, where now we crawl.

As to the physical problems presented by the moon, the questions relating to the light and heat — the radiant energy — it sends us, and to its temperature, seem to be the most attractive at present, especially for the reason that the results of the most recent investigators seem partially to contradict those obtained by their predecessors some years ago. It now looks as if we should have to admit that nearly all we receive from the moon is simply *reflected* radiation, and that the temperature of the lunar surface nowhere rises as high as the freezing-point of water, or even of mercury. At the same time, some astronomers of reputation are not disposed to admit such an upsetting of long-received ideas; and it is quite certain, that, in the course of the next few years, the subject will be carefully and variously investigated.

Closely connected with this is the problem of a lunar atmosphere —if, indeed, she have any.

Then there is the very interesting discussion concerning changes upon the moon's surface. Considering the difference between our modern telescopes and those employed fifty or a hundred years ago, I think it still far from certain that the differences between the representations of earlier and later observers necessarily imply any real alterations. But they, no doubt, render it considerably probable that such alterations have occurred, and are still in progress, and they justify a persistent, careful, minute, and thorough study of the details of the lunar surface with powerful instruments: especially do they inculcate the value of large-scale photographs, which can be preserved for future comparison as unimpeachable witnesses.

I will not leave the moon without a word in respect to the remarkable speculations of Professor George Darwin concerning the tidal evolution of our satellite. Without necessarily admitting all the numerical results as to her age and her past and future history, one may certainly say that he has given a most plausible and satisfactory explanation of the manner in which the present state of things might have come about through the operation of causes known and recognized, has opened a new field of research, and shown the way to new dominions. The introduction of the doctrine of the conservation of energy, as a means of establishing the conditions of motion and configuration in an astronomical system, is a very important step.

In the planetary system we meet, in the main, the same problems as those that relate to the moon, with a few cases of special interest.

For the most part, the accordance between theory and observation in the motions of the larger planets is as close as could be expected. The labors of Leverrier, Hill, Newcomb, and others, have so nearly cleared the field, that it seems likely that several decades will be needed to develop discrepancies sufficient to furnish any important corrections to our present tables. Leverrier himself, however, indicated one striking and significant exception to the general tractableness of the planets. Mercury, the nearest to the sun, and the one, therefore, which ought to be the best behaved of all, is rebellious to a certain extent: the perihelion of its orbit moves around the sun more rapidly than can be explained by the action of the other known planets. The evidence to this

effect has been continually accumulating ever since Leverrier first announced the fact, some thirty years ago; and the recent investigation by Professor Newcomb, of the whole series of observed transits, puts the thing beyond question. Leverrier's own belief (in which he died) was, that the effect is due to an unknown planet or planets between Mercury and the sun; but, as things now stand, we think that any candid investigator must admit that the probability of the existence of any such body or bodies of considerable dimensions is vanishingly small. We do not forget the numerous instances of round spots seen on the solar disk, nor the eclipse-stars of Watson, Swift, Trouvelot, and others; but the demonstrated possibility of error or mistake in all these cases, and the tremendous array of negative evidence from the most trustworthy observers, with the best equipment and opportunity, make it little short of certain that there is no Vulcan in the planetary system.

A ring of meteoric matter between the planet and the sun might account for the motion of the perihelion; but, as Newcomb has suggested, such a ring would also disturb the *nodes* of Mercury's orbit. It has been surmised that the cause may be something in the distribution of matter within the solar globe, or some variation in gravitation from the exact law of the inverse square, or some supplementary electric or magnetic action of the sun, or some special effect of the solar radiation, sensible on account of the planet's proximity, or something peculiar to the region in which the planet moves; but as yet no satisfactory explanation has been established.

Mercury still defies all our attempts to ascertain the length of its day, and the character and condition of its surface. Apparently the instruments and methods now at command are insufficient to cope with the difficulties of the problem; and it is not easy to say how it can be successfully attacked.

With Venus, the earth's twin-sister, the state of things is a little better: we do already know, with some degree of approximation. her period of rotation; and the observations of the last few months bid fair, if followed up, to determine the position of her poles, and possibly to give us some knowledge of her mountains, continents, and seas.

It would be rash to say of Mars that we have reached the limit of possible knowledge as regards a planet's surface; but the main facts are now determined, and we have a rather surprising amount

of supposed knowledge regarding his geography. By "supposed I mean merely to insinuate a modest doubt whether some of the map-makers have not gone into a little more elaborate detail than the circumstances warrant. At any rate, while the "Areographies" agree very well with each other in respect to the planet's more important features, they differ widely and irreconcilably in minor points.

Of the asteroids there is but little to be said. We are rather reluctantly obliged to admit that it is a part of our scientific duty as astronomers to continue to search for the remaining members of the group; at least, I suppose so, although the family has already become embarrassingly large. Still I think we are likely to learn as much about the constitution, genesis, and history of the solar system from these little flying rocks as from their larger relatives; and the theory of perturbations will be forced to rapid growth in dealing with the effects of Jupiter and Saturn upon their motions.

Nor is it unlikely that some day the hunter for this small game may be rewarded by the discovery of some great world, as yet unknown, slow moving in the outer desolation beyond the remotest of the present planetary family. Some configurations in certain cometary orbits, and some almost evanescent peculiarities in Neptune's motions, have been thought to point to the existence of such a world; and there is no evidence, nor even a presumption against it.

As regards the physical features of the asteroids, we at present know practically nothing: the field is absolutely open. Whether it is worth any thing may be a question; and yet, if one *could* reach it, I am persuaded that a knowledge of the substance, form, density, rotation, temperature, and other physical characteristics, of one of these little vagabonds, would throw vivid light on the nature and behavior of interplanetary space, and would be of great use in establishing the physical theory of the solar system.

The planet Jupiter, lordliest of them all, still, as from the first, presents problems of the highest importance and interest. A sort of connecting-link between suns and planets, it seems as if, perhaps, we might find, in the beautiful and varied phenomena he exhibits, a kind of halfway house between familiar terrestrial facts and solar mysteries. It appears quite certain that no analogies drawn from the earth and the earth's atmosphere alone will explain the strange things seen upon his disk, some of which, especially the anomalous

differences observed between the rotation periods derived from the observation of markings in different latitudes, are very similar to what we find upon the sun. "The great red spot" which has just disappeared, after challenging for several years our best endeavors to understand and explain it, still, I think, remains as much a mystery as ever, — a mystery probably hiding within itself the master-key to the constitution of the great orb of whose inmost nature it was an outward and most characteristic expression. The same characteristics are also probably manifested in other less conspicuous but equally curious and interesting markings on the varied and ever-changing countenance of this planet; so that, like the moon, it will well repay the most minute and assiduous study.

Its satellite system deserves careful observation, especially in respect to the eclipses, since we find in them a measure of the time required for light to cross the orbit of the earth, and so of the solar parallax; and also because, as has been already mentioned, they furnish a test of the constancy of the earth's rotation. The photometric method of observing these eclipses, first instituted by Professor Pickering at Cambridge in 1878, and since re-invented by Cornu in Paris, has already much increased the precision of the results.

With reference to the mathematical theory of the motion of these satellites, the same remarks apply as to the planetary theory. As yet nothing appears in the problem to be beyond the power and scope of existing methods, when carried out with the necessary care and prolixity; but a new and more compendious method is most desirable.

The problems of Saturn are much the same as those of Jupiter, excepting that the surface and atmospheric phenomena are less striking, and more difficult of observation. But we have, in addition, the wonderful rings, unique in the heavens, the loveliest of all telescopic objects, the type and pattern, I suppose, of world-making, in actual progress before our eyes. There seems to be continually accumulating evidence from the observations of Struve, Dawes, Henry, and others, that these whirling clouds are changing in their dimensions and in the density of their different parts; and it is certainly the duty of every one who has a good telescope, a sharp eye, and a chastened imagination, to watch them carefully, and set down exactly what he sees. It may well be that even a few decades will develop most important and instructive phenomena

in this gauzy girdle of old Chronos. Great care, however, is needed in order not to mistake fancies and illusions for solid facts. Not a few anomalous appearances have been described and commented on, which failed to be recognized by more cautious observers with less vivid imaginations, more trustworthy eyes, and better telescopes.

The outer planets, Uranus and Neptune, until recently, have defied all attempts to study their surface and physical characteristics. Their own motions and those of their satellites, have been well worked out; but it remains to discuss their rotation, topography, and atmospheric peculiarities. So remote are they, and so faintly illuminated that the task seems almost hopeless; and yet, within the year or two, some of our great telescopes have revealed faint and evanescent marking upon Uranus, which may in time lead to further knowledge of that far-off relative. Perhaps, the telescope of the future will give us some such views of Neptune as we now get of Jupiter.

There is a special reason for attempts to determine the rotation periods of the planets, in the fact that there is very possibly some connection between these periods, on the one hand, and, on the other, the planets' distances from the sun, their diameters and masses. More than thirty years ago, Professor Kirkwood supposed that he had discovered the relation in the analogy which bears his name. The materials for testing and establishing it were then, however, insufficient, and still remain so, leaving far too many of the data uncertain and arbitrary. Could such a relation be discovered, it could hardly fail to have a most important significance with respect to theories of the origin and development of the planetary system.

The great problem of the absolute dimensions of our system is, of course, commanded by the special problem of the solar parallax; and this remains a problem still. Constant errors of one kind or another, the origin of which is still obscure, seem to affect the different methods of solution. Thus, while experiments upon the velocity of light and heliometric measurements of the displacements of Mars among the stars agree remarkably in assigning a smaller parallax (and greater distance of the sun) than seems to be indicated by the observations of the late transits of Venus, and by methods founded on the lunar motions, on the other hand, the meridian observations of Mars all point to a larger parallax

and smaller distance. While still disposed to put more confidence in the methods first named, I, for one, must admit that the margin of probable error seems to me to have been rather increased than diminished by the latest published results deduced from the transits. I do not feel so confident of the correctness of the value 8″.80 for the solar parallax as I did three years ago. In its very nature, this problem is one, however, that astronomers can never have done with. So fundamental is it, that the time will never come when they can properly give up the attempt to increase the precision of their determination, and to test the received value by every new method that may be found.

The problems presented by the Sun alone might themselves well occupy more than the time at our disposal this evening. Its mass, dimensions, and motions, as a whole, are, indeed, pretty well determined and understood; but when we come to questions relating to its constitution, the cause and nature of the appearances presented upon its surface, the periodicity of its spots, its temperature, and the maintenance of its heat, the extent of its atmosphere, and the nature of the corona, we find the most radical differences of opinion.

The difficulties of all solar problems are, of course, greatly enhanced by the enormous difference between solar conditions and the conditions attainable in our laboratories. We often reach, indeed, similarity sufficient to establish a bond of connection, and to afford a basis for speculation; but the dissimilarity remains so great as to render quantitative calculations unsafe, and make positive conclusions more or less insecure. We can pretty confidently infer the presence of iron and hydrogen and other elements in the sun by appearances which we can reproduce upon the earth; but we cannot safely apply empirical formulæ (like that of Dulong and Petit, for instance), deduced from terrestrial experiments, to determine solar temperatures; such a proceeding is an unsound and unwarrantable extrapolation, likely to lead to widely erroneous conclusions.

For my own part, I feel satisfied as to the substantial correctness of the generally received theory of the sun's constitution, which regards this body as a great ball of intensely heated vapors and gases, clothed outwardly with a coat of dazzling clouds formed by the condensation of the less volatile substances into drops and

crystals like rain and snow. Yet it must be acknowledged that this hypothesis is called in question by high authorities, who maintain, with Kirchhoff and Zöllner, that the visible photosphere is no mere layer of clouds, but either a solid crust, or a liquid ocean of molten metals; and there may be some who continue to hold the view of the elder Herschel (still quoted as authoritative in numerous school-books), that the central core of the sun is a solid and even habitable globe, having the outer surface of its atmosphere covered with a sheet of flame maintained by some action of the matter diffused in the space through which the system is rushing. We must admit that the question of the sun's constitution is not yet beyond debate.

And not only the constitution of the sun itself, but the nature and condition of the matter composing it, is open to question. Have we to do with iron and sodium and hydrogen as we know them on the earth, or are the solar substances in some different and more elemental state?

However confident many of us may be as to the general theory of the constitution of the sun, very few, I imagine, would maintain that the full explanation of sun-spots and their behavior has yet been reached. We meet continually with phenomena, which, if not really contradictory to prevalent ideas, at least do not find in them an easy explanation.

So far as mere visual appearances are concerned, I think it must be conceded, that the most natural conception is that of a dark chip or scale thrown up from beneath, like scum in a caldron, and floating, partly submerged, in the blazing flames of the photosphere which overhang its edges, and bridge across it, and cover it with filmy veils, until at last it settles down again and disappears. It hardly *looks* like a mere hollow filled with cooler vapor, nor is its appearance that of a cyclone seen from above. But then, on the other hand, its spectrum under high dispersion is very peculiar; not at all that of a solid, heated slag, but it is made up of countless fine dark lines, packed almost in contact, showing, however, here and there, a bright line, or at least an interspace where the rank is broken by an interval wider than that which elsewhere separates the elementary lines,— a spectrum, which, so far as I know, has not yet found an analogue in any laboratory experiment. It seems, however, to belong to the type of absorption spectra, and to indicate, as the accepted theory requires, that the spot is dark in

consequence of loss of light, and not from any original defect of luminosity. Here, certainly, are problems that require solution.

The problem of the sun's peculiar rotation and equatorial acceleration is a most important one and still unsolved. Probably its solution depends in some way upon a correct understanding of the exchanges of matter going on between the interior and the surface of the fluid, cooling globe. It is a significant fact (already alluded to), that a similar relation appears to hold upon the disk of Jupiter; the bright spots near the equator of the planet completing their rotation about five minutes more quickly than the great red spot, which was forty degrees from the equator. It is hardly necessary to say that an astronomer, watching our terrestrial clouds from some external station (on the moon, for instance), would observe just the reverse. On the earth, equatorial clouds complete their revolution more slowly than those in our own latitude. *Our* storms travel toward the east, while the volcanic dust from Krakatoa moved swiftly west. We may at least conjecture that the difference between different planets somehow turns upon the question, whether the body whose atmospheric currents we observe is receiving more heat from without than it is throwing off itself.

Whatever may be the true explanation of this peculiarity in the motion of sun-spots, it will, when reached, probably carry with it the solution of many other mysteries, and will arbitrate conclusively between rival hypotheses.

The periodicity of the sun-spots suggests a number of important and interesting problems; relating, on the one hand, to its mysterious cause, and, on the other, to the possible effects of this periodicity upon the earth and its inhabitants. I am no "sun-spottist" myself, and am doubtful whether the terrestrial influence of sun-spots amounts to anything worth speaking of, except in the direction of magnetism. But all must concede that this is by no means yet demonstrated (it is not easy to prove a negative); and there certainly are facts and presumptions enough tending the other way to warrant more extended investigation of the subject. The investigation is embarrassed by the circumstance, pointed out by Dr. Gould, that the effects of sun-spot periodicity, if they exist at all (as he maintains they do), are likely to be quite different in different portions of the earth. The influence of changes in the amount of solar radiation will, he says, be first and chiefly

felt in alterations and deflections of the prevailing winds, thus varying the *distribution* of heat and rain upon the surface of the earth without necessarily much changing its absolute amount. In some regions it may, therefore, be warmer and dryer during a sun-spot maximum, while in adjoining countries it is the reverse.

There can be no question, that it is now one of the most important and pressing problems of observational astronomy to devise apparatus and methods delicate enough to enable the student to follow promptly and accurately the presumable changes in the daily, even the hourly, amounts of the solar radiation. It might, perhaps, be possible with existing instruments to obtain results of extreme value from observations kept up with persistence and scrupulous care for several years at the top of some rainless mountain, if such can be found; but the undertaking would be a difficult and serious affair, quite beyond any private means.

Related to this subject is the problem of the connection between the activity of the solar surface and magnetic disturbances on the earth,— a connection unquestionable as a matter of fact, but at present unexplained as a matter of theory. It may have something to do with the remarkable prominence of iron in the list of solar materials; or the explanation may, perhaps, be found in the mechanism by means of which the radiations of light and heat traverse interplanetary space, presenting itself ultimately as a corollary of the perfected electro-magnetic theory of light.

The chromosphere and prominences present several problems of interest. One of the most fruitful of them relates to the spectroscopic phenomena at the base of the chromosphere, and especially to the strange differences in the behavior of different spectrum-lines, which, according to terrestrial observations, are due to the same material. Of two lines (of iron, for instance) side by side in the spectrum, one will glow and blaze, while the other will sulk in imperturbable darkness; one will be distorted and shattered, presumably by the swift motion of the iron vapor to which it is due, while the other stands stiff and straight.

Evidently there is some deep-lying cause for such differences; and as yet no satisfactory explanation appears to have been reached, though much ingenious speculation has been expended upon it. Mr. Lockyer's bold and fertile hypothesis, already alluded to, that at solar and stellar temperatures our elements are decomposed into others more elemental yet, seems to have failed

of demonstration thus far, and rather to have lost ground of late; and yet one is almost tempted to say, "It *ought* to be true," and to add that there is more than a possibility that its essential truth will be established some time in the future.

Probably all that can be safely said at present is, that the spectrum of a metallic vapor (iron, for instance, as before) depends not only upon the chemical element concerned, but also upon its physical conditions; so that, at different levels in the solar atmosphere, the spectrum of the iron will differ greatly as regards the relative conspicuousness of different lines; and so it will happen, that, whenever any mass of iron vapor is suffering disturbance, those lines only which particularly characterize the spectrum of iron in that special state will be distorted or reversed, while all their sisters will remain serene.

The problem of the solar corona is at present receiving much attention. The most recent investigations concerning it — those of Dr. Huggins and Professor Hastings — tend in directions which appear to be diametrically opposite. Dr. Huggins considers that he has succeeded in photographing the corona in full sunshine, and so in establishing its objective reality as an immense solar appendage, sub-permanent in form, and rotating with the globe to which it is attached. One may call it "an atmosphere," if the word is not too rigidly interpreted. I am bound to say that plates which he has obtained do really show just such appearances as would be produced by such a solar appendage, though they are very faint and ghost-like. I may add further, that, from a letter from Dr. Huggins, recently received, I learn that he has been prevented from obtaining any similar plates in England this summer by the atmospheric haze, but that Dr. Woods, who has been provided with a similar apparatus, and sent to the Riffelberg in Switzerland, writes that he has "an assured success."

Our American astronomer, on the other hand, at the last eclipse (in the Pacific Ocean), observed certain phenomena which seem to confirm a theory he had formulated some time ago, and to indicate that the lovely apparition is an apparition only, a purely optical effect due to the *diffraction* (not *re*fraction, nor reflection either) of light at the edge of the moon — no more a solar appendage than a rainbow or a mock sun. There are mathematical considerations connected with the theory which may prove decisive when the paper of its ingenious and able proposer comes to be

published in full. In the meantime it must be frankly conceded that the observations made by him are very awkward to explain on any other hypothesis.

Whatever may be the result, the investigation of the status and possible extent of a nebulous envelope around a sun or star is unquestionably a problem of very great interest and importance. We shall be compelled, I believe, as in the case of comets, to recognize other forces than gravity, heat, and ordinary gaseous elasticity, as concerned in the phenomena. As regards the actual existence of an extensive gaseous envelope around the sun, it may be added that other appearances than those seen at an eclipse seem to demonstrate it beyond question,— phenomena such as the original formation of clouds of incandescent hydrogen at high elevations, and the forms and motions of the loftiest prominences.

But of all solar problems, the one which excites the deepest and most general interest is that relating to the solar heat, its maintenance and its duration. For my own part, I find no fault with the solution proposed by Helmholtz, who accounts for it mainly by the slow contraction of the solar sphere. The only objection of much force is, that it apparently limits the past duration of the solar system to a period not much exceeding some twenty millions of years; and many of our geological friends protest against so scanty an allowance. The same theory would give us, perhaps, half as much time for our remaining lifetime; but this is no objection, since there is no reason to deny the final cessation of the sun's activity, and the consequent death of the system. But while this hypothesis seems fairly to meet the requirements of the case, and to be a necessary consequence of the best knowledge we can obtain as to the genesis of our system and the constitution of the sun itself, it must, of course, be conceded that it does not yet admit of observational verification. No measurements within our power can test it, so far as appears at present.

It may be admitted, too, that much can be said in favor of other theories; such as the one that attributes the solar heat to the impact of meteoric matter, and that other most interesting and ingenious theory of the late Sir William Siemens.

As regards the former, however, I see no escape from the conclusion, that, if it were exclusively true, the earth ought to be receiving, as was pointed out by the late Professor Peirce, as much heat from meteors as from the sun. This would require the fall of a

quantity of meteoric matter,— more than sixty millions times as much as the best estimates make our present supply, and such as could not escape the most casual observation, since it would amount to more than a hundred and fifty[1] tons a day on every square mile.

As regards the theory of Siemens, the matter has been, of late, so thoroughly discussed, that we probably need spend no time upon it here. To say nothing as to the difficulties connected with the establishment of such a far-reaching vortex as it demands, nor of the fact that the temperature of the sun's surface appears to be above that of the dissociation point of carbon compounds, and hence above the highest heat of their combustion, it seems certainly demonstrated, that matter of the necessary density could not exist in interplanetary space without seriously affecting the planetary motions by its gravitating action as well as by its direct resistance; nor could the stellar radiations reach us, as they do, through a medium capable of taking up and utilizing the rays of the sun in the way this theory supposes.

And yet I imagine that there is a very general sympathy with the feeling that led to the proposal of the theory,— an uncomfortable dissatisfaction with received theories, because they admit that the greater part of the sun's radiant energy is, speaking from a scientific point of view, simply wasted. Nothing like a millionth part of the sky, as seen from the sun, is occupied, so far as we can make out, by objects upon which its rays can fall; the rest is vacancy. If the sun sends out rays in all directions alike, not one of them in a million finds a target, or accomplishes any useful work, unless there is in space some medium to utilize the rays, or unknown worlds, of which we have no cognizance, beyond the stars.

Now, for my own part, I am very little troubled by accusations of wastefulness against nature, or by demands for theories which will show what the human mind can recognize as "use" for all energy expended. Where I can perceive such use, I recognize it

[1] In an article on astronomical collisions, published in the *North-American Review* about a year ago, I wrongly stated the amount at fifty tons. There was some fatality connected with my calculations for that article. I gave the amount of heat due to the five hundred tons of meteoric matter, which is supposed to fall daily on the earth with an average velocity of fifteen miles per second, as fifty-three calories annually per square metre,— a quantity two thousand times too great. Probably the error would have been noticed if even the number given had not been so small, compared with the solar heat, as fully to justify my argument, which is only strengthened by the correction. I owe the correction to Professor LeConte of California, who called my attention to the error

with reverence and gratitude, I hope; but the failure to recognize it in other cases creates in my mind no presumption against the wisdom of nature, or against the correctness of an hypothesis otherwise satisfactory. It merely suggests human limitations and ignorance. How can one without sight understand what a telescope is good for?

At the same time, perhaps we assume with a little too much confidence, that, in free space, radiation does take place equally in all directions. Of course, if the received views as to the nature and conduct of the hypothetical "ether" are correct, there is no possibility of questioning the assumption; but, as Sir John Herschel and others have pointed out, the properties which must be ascribed to this "ether," to fit it for its various functions, are so surprising and almost inconceivable, that one may be pardoned for some reserve in accepting it as a finality. At any rate, as a fact, the question is continually started (the idea has been brought out repeatedly, in some cases by men of recognized scientific and philosophic attainment), whether the constitution of things may not be such that radiation and transfer of energy can take place only between ponderable masses; and that, too, without the expenditure of energy upon the transmitting-agent (if such exist) along the line of transmission, even *in transitu*. If this were the case, then, the sun would send out its energy only to planets and meteors and sister-stars, wasting none in empty space; and so its loss of heat would be enormously diminished, and the time-scale of the life of the planetary system would be correspondingly extended. So far as I know, no one has ever yet been able to indicate any kind of medium or mechanism by which vibrations, such as we know to constitute the radiant energy of light and heat, can be transmitted at all from sun to planet under such restrictions, and it is very difficult to see how any such limited transmission, confined to the lines of gravitational force, could be reconciled with the law of inverse squares. That this law of radiation actually holds in interplanetary space is of course demonstrated by the fact that the calculated brightness of a planet, at different places in its orbit and varying distances from the earth, agrees with the result of photometric observation. Still one ought not to be too positive in assertions as to the real condition and occupancy of so-called vacant space. The "ether" is a good working hypothesis, but hardly more as yet.

I need not add, that a most interesting and as yet inaccessible problem, connected with the preceding, is that of the mechanism of gravitation, and, indeed, of all forces that seem to act at a distance: as for that matter, in the last analysis, *all* forces do. If there really be an "ether," then it would seem that somehow all attractions and repulsions of ponderable matter must be due to its action. Challis's investigations and conclusions as to the effect of hydrodynamic actions in such a medium do not seem to have commanded general acceptance; and the field still lies open for one who will show how gravitation and other forces can be correlated with each other through the ether.

Meteors and the comets, seeming to belong neither to the solar system nor to the stellar universe, present a crowd of problems as difficult as they are interesting. Much has undoubtedly been gained during the last few decades, but in some respects that which has been learned has only deepened the mystery.

The problem of the origin of comets has been supposed to be solved to a certain extent by the researches of Schiaparelli, Heis, Professor Newton, and others, who consider them to be strangers coming in from outer space, sometimes "captured" by planets, and forced into elliptic orbits, so as to become periodic in their motion. Certainly this theory has strong supports and great authority, and probably it meets the conditions better than any other yet proposed. But the objections are really great, if not insuperable, — the fact that we have so few, if any, comets moving in hyperbolic orbits, as comets *met* by the sun would be expected to move; that there seems to be so little relation between the direction of the major axes of cometary orbits, and the direction of the solar motion in space; and especially the fact, pointed out and insisted upon by Mr. Proctor in a recent article, that the alteration of a comet's natural parabolic orbit to the observed elliptic one, by planetary action, implies a reduction of the comet's velocity greater than can be reasonably explained. If, for instance, Brorsen's comet (which has a mean distance from the sun a little more than three times that of the earth) was really once a parabolic comet, and was diverted into its present path by the attraction of Jupiter, as generally admitted, it must have had its velocity reduced from about eleven miles a second to five. Now, it is very difficult, if not out of the question, to imagine any possible configuration of

the two bodies and their orbits which could result in so great a change. While I am by no means prepared to indorse as conclusive all the reasoning in the article referred to, and should be very far from ready to accept the author's alternative theory (that the periodic comets have been ejected from the planets, and so are not their captives, but their children), I still feel that the difficulty urged against the received theory is very real, and not to be evaded, though it may possibly be overcome by future research.

Still more problematical is the constitution of these strange objects of such enormous volume and inconceivable tenuity, self-luminous and transparent, yet reflecting light, the seat of forces and phenomena unparalleled in all our other experience. Hardly a topic relating to their appearance and behavior can be named which does not contain an unsolved problem. The varying intensity, polarization, and spectroscopic character of their light; the configurations of the nucleus and its surrounding nebulosity; and especially the phenomena of jets, envelopes, and tail, — all demand careful observation and thorough discussion.

I think it may be regarded as certain, that the explanation of these phenomena when finally reached, if that time ever come, will carry with it, and be based upon, an enormous increase in our knowledge as to the condition, contents, and temperature of interplanetary space, and the behavior of matter when reduced to the lowest terms of density and temperature.

Time forbids any adequate discussion of the numerous problems of stellar astronomy. Our work, in its very nature incessant and interminable, consists, of course, in the continual observation and cataloguing of the places of the stars, with ever-increasing precision. These star-places form the scaffold and framework of all other astronomical investigations involving the motions of the heavenly bodies; they are the reference-points and bench-marks of the universe. Ultimately, too, the comparison of catalogues of different dates will reveal the paths and motions of all the members of the starry host, and bring out the great orbit of the sun and his attendant planets.

Meanwhile, micrometric observations are in order upon the individual stars in different clusters, to ascertain the motions which occur in such a case; and the mathematician is called upon again to solve the problem of such movement.

Now, too, since the recent work of Gill and Elkin in South Africa, and of Struve, Hall, and others, elsewhere, upon stellar parallax, new hopes arise that we may soon come to some wider knowledge of the subject; that, instead of a dozen or so parallaxes of doubtful precision, we may get a hundred or more relating to stars of widely different brightness and motion, and so be enabled to reach some trustworthy generalizations as to the constitution and dimensions of the stellar universe, and the actual rates of stellar and solar motion in space.

Most interesting, also, are the studies now so vigorously prosecuted by Professor Pickering in this country, and many others elsewhere, upon the brightness of the stars, and the continual variations in this brightness. Since 1875, stellar photometry has become almost a new science.

Then, there are more than a myriad of double and multiple stars to watch, and their orbits to be determined; and the nebulæ claim keen attention, since some of them appear to be changing in form and brightness, and are likely to reveal to us some wonderful secrets in the embryology of worlds.

Each star also presents a subject for spectroscopic study; for although, for the most part, the stars may be grouped into a very few classes from the spectroscopic point of view, yet, in detail, the spectra of objects belonging to the same group differ considerably and significantly, almost as much as human faces do.

For such investigations, new instruments are needed, of unexampled powers and accuracy, some for angular measurement, some for mere power of seeing. Photography comes continually more and more to the front; and the idea sometimes suggests itself, that by and by the human eye will hardly be trusted any longer for observations of precision, but will be superseded by an honest, unprejudiced, and unimaginative plate and camera. The time is not yet, however, most certainly. Indeed, it can never come at all, as relates to certain observations; since the human eye and mind together integrate, so to speak, the impressions of many separate and selected moments into one general view, while the camera can only give a brutal copy of an unselected state of things, with all its atmospheric and other imperfections.

New methods are also needed, I think (they are unquestionably possible), for freeing time-observations from the errors of personal equation; and increased precision is demanded, and is being pro-

gressively attained, in the prevention, or elimination, of instrumental errors, due to differences of temperature, to mechanical strains, and to inaccuracies of construction. Astronomers are now coming to the investigation of quantities so minute, that they would be completely masked by errors of observation that formerly were usual and tolerable. The science has reached a stage, where, as was indicated at the beginning of this address, it has to confront and deal with the possible unsteadiness of the earth's rotation, and the instability of its axis. The astronomer has now to reverse the old maxim of the courts; for him, and most emphatically at present, *de minimis curat lex.* Residuals and minute discrepancies are the seeds of future knowledge, and the very foundations of new laws.

And now, in closing this hurried and inadequate, but I fear rather tedious, review of the chief problems that are at present occupying the astronomer, what answer can we give to him who insists, *Cui bono?* and requires a reason for the enthusiasm that makes the votaries of our science so ardent and tireless in its pursuit? Evidently very few of the questions which have been presented have much to do directly with the material welfare of the human race. It may possibly turn out, perhaps, that the investigation of the solar radiation, and the behavior of sun-spots, may lead to some better understanding of terrestrial meteorology, and so aid agricultural operations and navigation. I do not say it will be so, — in fact, I hardly expect it, — but I am not sure it will not. Possibly, too, some few other astronomical investigations may facilitate the determination of latitudes and longitudes, and so help exploration and commerce; but, with a few exceptions, it must be admitted that modern astronomical investigations have not the slightest commercial value.

Now, I am not one of those who despise a scientific truth or principle because it admits of an available application to the affairs of what is called "practical life," and so is worth something to the community in dollars and cents: its commercial value is — just what it is — to be accepted gratefully.

Indirectly, however, almost all scientific truth has real commercial value, because "knowledge is power," and because (I quote it not irreverently) "the truth shall make you free," — any truth, and to some extent; that is to say, the intelligent and intellectu-

ally cultivated will generally obtain a more comfortable livelihood, and do it more easily, than the stupid and the ignorant. Intelligence and brains are most powerful allies of strength and hands in the struggle for existence; and so, on purely economical grounds, all kinds of science are worthy of cultivation.

But I should be ashamed to rest on this lower ground: the highest value of scientific truth is not economic, but different and more noble; and, to a certain and great degree, its truest worth is more as an object of pursuit than of possession. The "practical life"— the eating and the drinking, the clothing and the sheltering — comes *first*, of course, and is the necessary foundation of any thing higher; but it is not the whole or the best or the most of life. Apart from all spiritual and religious considerations (which lie one side of our relations in this association), there can be no need, before this audience, to plead the higher rank of the intellectual, æsthetic, and moral life above the material, or to argue that the pabulum of the mind is worth as much as food for the body. Now, it is unquestionable, that, in the investigation and discovery of the secrets and mysteries of the heavens, the human intellect finds most invigorating exercise, and most nourishing and growth-making aliment. No other scientific facts and conceptions are more effective in producing a modest, sober, truthful, and ennobling estimate of man's just place in nature, both of his puny insignificance, regarded as a physical object, and his towering spirit, in some sense comprehending the universe itself, and so akin to the divine.

A nation oppressed by poverty, and near to starving, needs first, most certainly, the trades and occupations that will feed and clothe it. When bodily comfort has been achieved, then higher needs and wants appear; and then science, for truth's own sake, comes to be loved and honored along with poetry and art, leading men into a larger, higher, and nobler life.

# REPORTS OF COMMITTEES.

## SECOND REPORT OF THE COMMITTEE ON STANDARDS OF STELLAR MAGNITUDES.

THE first report of this Committee (*Proc. Amer. Assoc. XXX*, p. 1) included a plan for the determination of standards for stars fainter than the tenth magnitude. Twenty-four bright equatorial stars were chosen and the standards were to be selected from the regions following them from two to six minutes of time and not differing in declination from the leading stars by more than five minutes of arc. The observations described below have been made at the Harvard College Observatory unless otherwise stated. The light of each of the leading stars has been determined on from seven to eighteen nights with the meridian photometer. Charts have been constructed of all the stars visible with the fifteen inch telescope, in all but three of the regions from which the standards are to be selected. Most of these charts have been submitted to a careful scrutiny with the fifteen inch telescope of the Washburn Observatory. An important test of the completeness of the charts is thus afforded.

In the following table three successive columns give the names of the twenty-four leading stars and their approximate right ascensions and declinations for 1880. The next two columns give the number of nights on which they were observed with the meridian photometer, and the resulting magnitude. The details of these measures and a comparison with various other determinations of their light will be found in the *Harv. Observ. Annals*, Vol. XIV. The last columns give the number of stars in each of the charts, and the corresponding number of stars contained in the same portions of the Durchmusterung.

Stars suitable for standards must next be selected by the help of the charts. The light of these stars should then be measured in as many different ways as possible. The Committee will be much indebted for aid that may be rendered them in this portion of their work. The early publication of the charts now becomes a matter of importance, as it would permit their immediate use for various purposes.

| NAME. | R. A. 1880. | | Dec. 1880. | | No. Nights. | Phot. Mag. | Stars on Ch. | D. M. Stars. |
|---|---|---|---|---|---|---|---|---|
| | h. | m. | | | | | | |
| γ Pegasi | 0 | 7.1 | + 14° | 31′ | 13 | 3.04 | 49 | 3 |
| θ′ Ceti | 1 | 18.0 | — 8 | 48 | 12 | 3.77 | 27 | — |
| α Piscium | 1 | 55.9 | + 2 | 11 | 12 | 3.99 | — | 1 |
| α Ceti | 2 | 56.0 | + 3 | 37 | 11 | 2.68 | — | 2 |
| γ Eridani | 3 | 52.4 | — 13 | 51 | 10 | 3.05 | 30 | — |
| α Tauri | 4 | 29.0 | + 16 | 16 | 16 | 1.00 | 19 | 3 |
| ε Orionis | 5 | 30.1 | — 1 | 17 | 16 | 1.76 | 42 | 6 |
| γ Geminorum | 6 | 30.8 | + 16 | 30 | 17 | 2.00 | 150 | 5 |
| α Canis Minoris | 7 | 33.0 | + 5 | 32 | 15 | 0.46 | 96 | 3 |
| ε Hydræ | 8 | 40.4 | + 6 | 51 | 7 | 3.58 | 64 | 4 |
| α Leonis | 10 | 2.0 | + 12 | 33 | 15 | 1.42 | 39 | 1 |
| θ Leonis | 11 | 7.9 | + 16 | 5 | 10 | 3.47 | 24 | 3 |
| η Virginis | 12 | 13.8 | + 0 | 0 | 10 | 4.05 | 23 | 2 |
| α Virginis | 13 | 18.9 | — 10 | 32 | 13 | 1.23 | 30 | — |
| α Bootis | 14 | 10.2 | + 19 | 48 | 13 | 0.03 | 25 | 1 |
| β Libræ | 15 | 10.5 | — 8 | 56 | 14 | 2.74 | 39 | — |
| δ Ophiuchi | 16 | 8.1 | — 3 | 23 | 11 | 2.77 | 48 | — |
| η Ophiuchi | 17 | 3.5 | — 15 | 34 | 10 | 2.62 | 100 | — |
| η Serpentis | 18 | 15.1 | — 2 | 56 | 10 | 3.35 | 7 | — |
| δ Aquilæ | 19 | 19.4 | + 2 | 53 | 14 | 3.46 | — | 3 |
| Aquilæ | 20 | 5.1 | — 1 | 11 | 10 | 3.39 | 110 | 2 |
| β Aquarii | 21 | 25.2 | — 6 | 6 | 10 | 3.14 | 52 | — |
| α Aquarii | 21 | 59.6 | — 0 | 54 | 10 | 3.16 | 48 | 0 |
| α Pegasi | 22 | 58.8 | + 14 | 34 | 18 | 2.61 | 29 | 3 |

Respectfully submitted,

EDWARD C. PICKERING, *Chairman.*
LEWIS BOSS.
S. W. BURNHAM.
ASAPH HALL.
WILLIAM HARKNESS.
EDWARD S. HOLDEN.
SIMON NEWCOMB.
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ORMOND STONE.
C. A. YOUNG.

## Report of the Committee on Indexing Chemical Literature.

The Committee on Indexing Chemical Literature appointed in 1882 respectfully presents the following report of progress.

We have the pleasure to announce that since our last Report the following Indexes have been published by their authors, the arrangement of material being uniform with that of those previously issued.

Ozone, *second index*, by Prof. Albert R. Leeds.

Peroxide of Hydrogen, *second index*, by Prof. A. R. Leeds.

Speed of Chemical Reactions, by Prof. R. B. Warder.

Starch Sugar, by Dr. E. J. Hallock.

Besides these a valuable contribution to chemical bibliography has been independently published on a somewhat different plan, by Professor Albert B. Prescott and Mr. J. W. Baird. The full titles of the above will be found at the close of this Report.

Two hundred and fifty copies of our Report for 1883 have been sent to chemists throughout the United States, the Smithsonian Institution having kindly attended to the distribution by mail without expense to the Committee. This led to correspondence with several chemists who regarded the scheme of coöperative indexing favorably, and resulted in several offers of assistance.

Professor Wm. Ripley Nichols offers an Index to the Literature of Carbon monoxide.

Professor L. P. Kinnicutt offers an Index to the Literature of Meteorites.

Dr. Henry Leffmann reports progress on his Index to the Literature of Arsenic.

Professor C. E. Monroe does likewise with reference to an Index to the Literature of Explosives.

Professor A. B. Prescott and Mr. J. T. Craig offer an Index to the Literature of Phosphorus.

Dr. H. Carrington Bolton has in preparation a second index to the Literature of Uranium.

An offer was also received of an Index to an element already on the list of those published, but was withdrawn as soon as the author had his attention called to the existing publication. This circumstance shows forcibly the advantage of coöperation through this Committee.

We are pleased to announce that in consequence of our representations the Smithsonian Institution has consented to publish Indexes to Chemical Literature which shall be endorsed by this Committee. The Smithsonian places a limit to the number of pages which will be printed per annum, but the limit is a generous one.

By thus securing the assistance of the Smithsonian Institution, chemists are assured of a reliable and authoritative channel of publication, together with a wide circulation, and the plan of coöperative indexing will undoubtedly receive a great stimulus.

Finally, to extend more widely acquaintance with the existing Indexes, we append a complete list of those printed. A limited number of those published by the New York Academy of Sciences can be had by addressing the Chairman of the Publication Committee of the Academy, Prof. D. S. Martin, 236 West 4th Street, New York City.

Respectfully submitted,

H. CARRINGTON BOLTON, *Chairman.*
IRA REMSEN.
F. W. CLARKE.
ALBERT R. LEEDS.
ALEXIS A. JULIEN.

*Sept.* 4, 1884.

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LIST OF INDEXES TO CHEMICAL LITERATURE.

*Uranium*, Index to the Literature of. By H. Carrington Bolton. Annals of the New York Lyceum of Natural History, Vol. IX, February, 1870. 15 pp. 8vo.

*Manganese*, Index to the Literature of; 1596–1874. By H. Carrington Bolton. Annals of the Lyceum of Natural History, New York, Vol. XI, November, 1875. 44 pp. 8vo.

*Titanium*, Index to the Literature of; 1783–1876. By Edw. J. Hallock. Annals of the N. Y. Academy of Sciences, Vol. I, Nos. 2 & 3, 1877. 22 pp. 8vo.

*Vanadium*, Index to the Literature of. By G. Jewett Rockwell. Annals of the N. Y. Academy of Sciences, Vol. I, No. 5, 1877. 13 pp. 8vo.

*Ozone*, Index to the Literature of; 1875–1879. By Albert R. Leeds. Annals of the N. Y. Academy of Sciences, Vol. I, No. 12, 1880. 32 pp. 8vo.

*Peroxide of Hydrogen*, The Literature of; 1818–1878. By Albert R. Leeds. Annals of the N. Y. Academy of Sciences, Vol I, No. 13, 1880. 11 pp. 8vo.

*Electrolysis*, Index to the Literature of; 1784–1880. By W. Walter Webb. Annals of N. Y. Academy of Sciences, Vol. II, No. 10, 1882. 40 pp. 8vo.

*Speed of Chemical Reactions*, Literature of. By Robert B. Warder. Proceedings of the Am. Assoc. Adv. Science, Vol. 32, 1883. 3 pp. 8vo.

*Starch-Sugar*, Bibliography of. By Edw. J. Hallock. Appendix E to Report on Glucose prepared by the Natural Academy of Sciences in response to a request made by the Commissioner of Internal Revenue. U. S. Internal Revenue, Washington, D. C., 1884. 44 pp. 8vo.

*Ozone*, Index to the Literature of (1879–1883); accompanied by an Historical-Critical Résumé of the Progress of Discovery since 1879. By Albert R. Leeds. Annals N. Y. Academy of Sciences, Vol. III, p. 137, 1884. 16 pp. 8vo.

*Peroxide of Hydrogen*, Index to the Literature of; 1879–1883. By Albert R. Leeds. Annals N. Y. Academy of Sciences, Vol. III, p. 153, 1884. 3 pp. 8vo.

*Dictionary of the Action of Heat upon Certain Metallic Salts*, including an Index to the principal Literature upon the Subject. Compiled and arranged by J. W. Baird, contributed by A. B. Prescott. New York, 1884. 70 pp., 8vo.

# SECTION A.

# MATHEMATICS AND ASTRONOMY.

# ADDRESS

BY

## PROFESSOR HENRY T. EDDY,

VICE PRESIDENT, SECTION A.

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### *COLLEGE MATHEMATICS.*

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In a survey of the general interests for the advancement of which this section of Mathematics and Astronomy has now met, it has seemed to me that there is one subject in the consideration of which you all must have a vital interest. And as this is also a subject of daily professional interest to myself, and closely concerns the future welfare of this association, as well as the progress of science in our land, I may be pardoned for pressing it upon your attention and stating, so far as I may be able, the truth as it appears to me. The subject I refer to is the present state of mathematical training in our colleges; its aims, its needs, and its relations to education and to scientific research. I am the more willing to speak upon this subject because I feel that my opportunities for experience, though they perhaps have not been of so great duration as others have enjoyed, have, nevertheless, been varied, and of such a kind as possibly to be useful in awakening thought and in bringing to light the experience of others upon this important part of our college study, a part, I may say, which has been almost completely overlooked in the earnest controversy which has arisen during the past year, respecting the attitude of our colleges toward the various branches of learning, ancient and modern, embraced in their curricula.

As the thoughts I have to present are based largely on personal experience, I may be pardoned for saying that this experience commenced twenty-one years ago on entering the freshman class at Yale College, and after graduation it was continued as a student

in the Sheffield Scientific School. Since then it has been my lot to be constantly engaged in teaching pure and applied mathematics: at first in a southern university, then four years at Cornell, one year at Princeton, and now for ten years in the University of Cincinnati, one of the youngest of our western colleges. It will be seen from this enumeration that my experience has been distributed between classical institutions on the one hand, and scientific on the other, in such a way as would naturally make my prepossessions lie in favor of the established regime of our classical colleges. If my maturer convictions have led me to criticise their method and spirit, it is not from any preconceived animosity to them, but out of a sincere desire that they may be brought to occupy a position in our educational life which shall command the undivided support of the cultivated and best informed portion of the community.

One of the most unexpected revelations which this experience has made to me is that mathematical study in college is not necessarily drudgery.

I think I do not state the matter too strongly when I say that during the years in which I was an undergraduate, mathematical study was regarded with deep-seated aversion by the average student, an aversion not capable of adequate expression in any ordinary way. The burial of Euclid and the cremation of analytics were a mere joke; but the inward disgust and hatred of mathematics which existed in the minds of the students of my day left an impression not to be effaced in a lifetime. Now what was the cause of such pronounced hostility? The answer is not far to seek. The study was not interesting, and it was not well understood. These are two reasons which stand in the closest possible connection with each other. We might say, either that the study failed of being understood because it was uninteresting, or that it awakened no interest because it was not well understood. Both these statements were true. I have found the same state of affairs in every classical college respecting which I have had any intimate knowledge from that day to this. In them it is an article of faith firmly held, and oft expressed by the undergraduate, that higher mathematics is a study which can be thoroughly mastered only by exceptional geniuses, of which each college class possesses of course one or more brilliant specimens; and as to obtaining some reasonable understanding of the study, it is thought to be barely possi-

ble that ten per cent of the undergraduate world *could* do so by dint of severe application (such as no one is called on to make), were it worth the effort. For the large majority, however, such attainment is thought to be as impossible as for them to fly, since they are regarded as being wholly wanting in the organs necessary to the accomplishment of that feat. In this statement I am quite sure I have not misinterpreted undergraduate sentiment in those established and time-honored seats of classical learning which still hold, in effect, to a fixed curriculum that prescribes a certain amount of Latin, Greek and mathematics as requisite to the degree of bachelor of arts. The foundation for such a belief as this lies in the fact, patent to the eyes of all, that very few do really become in any true sense masters of the mathematical subjects which they study, or indeed have sufficient practice in the application of the principles they attempt to learn, to be capable of judging whether they have been so mastered as to accomplish the ends which should be sought in mathematical training. One very bad feature in this state of things is, that this sentiment respecting mathematical study is not confined to undergraduates, but is largely shared, not only by the general faculties of these institutions, but by the instructors and professors of mathematics as well, many of whom have been convinced by the facts just stated that nothing better is to be expected. They have come to regard mathematical study (in common with the rest of the college world), as an indispensable part of the scholastic discipline which ought in their estimation to be administered in proper amount to the undergraduate; but that mathematics should occupy any place of honor in his intellectual equipment or be one of the tools and methods of work by which he shall reason respecting the facts of nature, and discover the truth in matters of scientific or practical importance, they do not believe possible.

There are also various other reasons which have led mathematical teachers to a low opinion of this study besides the ill success that has attended their efforts in introducing their pupils to the world of mathematical activity: a world which has not only engrossed the principal interest and energy of a large number of the acutest minds of the past, but to-day absorbs a larger proportion of talent than ever before. Among these reasons, it must be admitted that it has too often happened that they have not themselves become engrossed in these activities, nay, perhaps

not even interested in them. That we have in this country no large body of men whose life-work has been, day by day, directed in the line of mathematical investigation is evident to all. The paucity of important mathematical investigations emanating from this side of the Atlantic is proof of it. The cultivators of this science among us, and the authors of valuable papers, have been, I think, quite often found in positions other than that of college professor. All this goes to show that the mathematical scholarship of the teaching force in our colleges is not equal to that of countries where mathematical research in its higher walks is the legitimate outcome of university instruction. It seems almost superfluous to insist that healthy and sustained progress in any abstract science must spring up and be carried forward under the fostering influence of established seats of learning, and that it is useless to rely upon volunteer support or upon instances of private devotion to these higher pursuits, which require the libraries and the atmosphere of university life in order to ensure continued growth. But even where the professorial chair is filled by an eager and brilliant mathematician, to whom his chosen study has all the witchery of an idolized pursuit, he often feels the hopelessness of initiating his pupils into this all-absorbing realm of thought in the few brief months at his disposal. This hopelessness becomes settled despair when it encounters, as it usually does, a state of profound apathy in the mind of the student.

Thus it has come to pass that, on account of these and other causes to which I may refer later on, there has been during the last two generations a relative decadence in mathematical study in the classical colleges of our country. I say a *relative* decadence not an actual decadence, because I mean to assert that in the gradual increase of the amount of study required for the degree of bachelor of arts during the last half century, and the consequent greater maturity of the recipients of that degree, the department of study which has been more largely concerned is that of the classics. Moreover, if the study of mathematics is necessarily as barren of good results with the great body of students, as I have described it to have been in the past, then it must be confessed by all who have the real interests of education at heart, that it has had all the time and attention it deserves in our college courses. I, for one, however, do not for an instant admit this to be the case. I am convinced that mathematics has been long and sadly

misused at the hands of its pretended cultivators—the classical colleges of this country. That this has been done ignorantly and in obedience to long-established educational usages makes it all the more imperative that we should make it our duty to see that so important a matter is rectified as soon as practicable. What the misuse of mathematical study of which I complain is, may perhaps be best apprehended from a statement of my own experience as an undergraduate. Entering college with the usual mathematical outfit, acquired in a country academy in Massachusetts, I was for three years of my college course daily examined on an assigned task in some mathematical text-book. It does not seem to me that my knowledge of mathematics was very materially increased during that time by this process. Certainly a good teacher could in three months' time, at the rate of one lesson per day, have taught me far more than I learned by the process to which I was subjected, and I have reason to believe that I was not an inapt nor an indolent student in this branch. This plain statement will, I think, render it clear what the difficulty was. The study was used simply as a form of mental discipline or intellectual gymnastics. The object sought was not to learn how to use this the most splendid instrument of intellectual research yet devised by the wit of man. Not at all; far otherwise; it was regarded only as an approved means for sharpening the faculties, for whetting the keenness of thought and intensifying mental concentration. Now all I have to say in regard to this is, that it did not do it; it went wide of the mark; and that too in face of the fact that I was a willing student of mathematics from an inherited love of the study. I have, since I left college, had some taste, as I believe, of the quickening power of mathematical thought, but I did not fall under its sway in college, nor did I even gain, what it might be thought quite possible to gain there, a facility in the algebraic and formal part of mathematical reasoning which would be of some permanent use. Of such training I had next to none. I do not think my case an exceptional one.

If this were the state of affairs in mathematics alone, it would be deplorable, but might be regarded as a necessary concomitant of the overmastering interest and influence of the study of Latin and Greek, which occupy a larger share of attention during the first half of the college course. But such is not the fact. The fact is that the habitual temper and attitude of college life is one

that tends to destroy every trace of intellectual appreciation for the studies embraced in the curriculum, and the tendency is so strong that it pretty effectively accomplishes that result. The pervading atmosphere in which the undergraduate exists and his daily environment are such that he can no more escape its deadly effects upon his intellectual life than he could a miasma or a malaria which comes from no one knows where. There is an underlying consciousness running through the whole scheme of education based upon classical study, that the objects of such study are not in themselves of vital importance to the student, but that their value is chiefly to be found in the reflex influence upon the person submitting to its discipline. Pretend to deceive ourselves as we may upon this point, the undergraduate feels this with every breath of his young life. By it he is led into habitual antagonism to his instructors, to his great detriment intellectually and morally. It carries a thousand evils in its train beside those which it is now our purpose to consider.

Now while it is undeniable that all liberal study is valuable for culture of the mind, and it is unquestionable that knowledge is a valuable possession, and the acquirement of it worth the most serious effort of every thinking being; yet it is still more indubitable that the value of any study from a disciplinary and educational point of view has a direct relation to the interest it awakens in the mind of the student. What zest is there in pursuits which awaken only inward disgust; or how are the best powers of the mind to be called forth by subjects of feeble interest? It is beyond contradiction that all of us have an appetite for mental food. The young man who goes to college is no exception to this remark, and the food he craves is of a high order too. I insist upon it that he should be supplied with a kind of intellectual pabulum suited both to his capacities and to his tastes. In order to do this it is essential that there be considerable freedom in college in the choice either of separate studies or courses of study, and that a fixed curriculum be no longer made compulsory.

The day is gone by when it is possible usefully to prescribe a course of mental discipline solely out of regard to its supposed disciplinary value. That is a relic of mediæval scholasticism. Our classical colleges are the strongholds of this scholasticism and there is need that we cry aloud and spare not, taking for our text the words: "the letter killeth, but the spirit maketh alive." The hollowness and mockery of such a proposition respecting

learning can only be rightly compared to that of the atheist who insists upon the value of prayer merely for its good influence upon the spirit of the petitioner. This world has too many great interests, too many living issues, even in mathematics, to permit the pall of such a piece of sham to darken the young life and wither the bloom of the intellectual hope of our land. I do not say this from a utilitarian point of view, nor do I for a moment take the position that classical study is in itself a delusion, nor that the ancient languages and philological science are not most worthy and inspiring objects of study for those who really intend to know something of them, or for those whose tastes and capacities fit them for their pursuit. But I do distinctly affirm that taken in the ordinary way, as a course of discipline, their effect is evil and evil continually. As a lover of sound learning and good education, I wish to express the conviction with all the emphasis I can, that not only is mathematical progress stayed by its baleful and palsying influence, but that this demoniacal spirit of study for the sake of discipline, which possesses our colleges, must be cast out before they can rightly train either classical or mathematical scholars, or stand where they should stand, in the forefront of higher culture in the liberal arts and sciences.

But to turn now from these severe animadversions, which I am sorry to feel truth compels me to utter, to brighter and more encouraging aspects of the question; I should be justly blameworthy for using such language in criticism of my time-honored alma mater and other foremost seats of classical culture were I not convinced not only of their truth but of the possibility of entirely removing most of the grounds for such criticism; and this by the introduction of a spirit of study very different from the disciplinary spirit, a spirit which for the lack of a better name we may call the scientific spirit; a spirit of sincere and earnest inquiry after knowledge. It is impossible for words of mine to convey to those who have not happened to live within the atmosphere of institutions pervaded by this spirit, any just conception of the mighty impulses and intellectual awakenings it calls forth in those young minds who by good fortune are educated under its influence.

This spirit is not inimical to classical study. It is inimical to no branch of liberal learning. It is the benign alma mater of every worthy intellectual pursuit. We have in this land many institutions full of the high endeavor which it inspires. These are, too

many of them, technological schools, and schools devoted to the study of the sciences. The reason is obvious; since these are subjects of instruction which appeal to the interest of a large proportion of the students who attend, the effort of the teacher is to convey a real knowledge of the subjects taught, the manner of teaching being a secondary matter; and further, these are not subjects which lend themselves readily to the disciplinary method. There is, however, apparently no reason why the spirit which so largely animates scientific study should be confined to that kind of study, for it is not the nature of the study which determines the spirit in which it shall be pursued.

Mathematics is a case very much in point in this regard. I have already stated the position which it occupies where the disciplinary spirit prevails. I could wish now to give you some conception of the place of honor which I have found it to occupy in the esteem, and I may say affections, of students in institutions where a spirit of free inquiry prevails; but I fear that I shall seem as one who out of an exuberant imagination unfolds a vision of Utopia. But where enthusiasm lights the torch marvels come to pass. The truth is, young men of spirit will not shirk hard work, if they are convinced that by it they can open up any fair field of knowledge which appears desirable. All I can say is, that under such influences, I have seen students gain, during the first half of their college course, such familiarity with those branches of higher analysis which are the common groundwork of modern investigation in analytical mechanics and mathematical physics, as to have really open to them the literature of these subjects, and this not in isolated instances merely, but with class after class.

I believe that it is the right of a student of the liberal arts in our colleges and universities to have such a training given him in his chosen pursuits as shall carry him to a point where the great generalization of that branch lies open to his view, and where he shall be able intelligently to begin his work as an independent student in that department of knowledge, if not as one of the working force of investigators in that department, with some just comprehension of its scopes and its processes. If this can be done in the case of mathematics there will, assuredly, be no difficulty in other departments. It is popularly supposed, as before stated, that the number fitted by nature for mathematical study is small. Such, I have been convinced against my preconceived opinions, is not the

fact. It is a study as much sought after, and pursued as eagerly as any other branch of liberal study, provided only that the teachers thereof are themselves men who have a live interest in the subject, are capable, patient and apt at giving instruction.

This leads me to discuss somewhat more in detail the scope of mathematical instruction in college.

The geometry of Euclid has long held a post of honor in the mathematics of the college course. The cause for this is easily seen. It is a subject which lends itself more readily than any other branch of mathematics to the form of discipline in vogue. What worlds of cruelty have been perpetrated in the name of mathematical drill in teaching Euclid! It is a study which ought not to be in the college course at all, but should be finished in the preparatory schools. The important mathematical truths arrived at by Euclid's methods are not very numerous, and it is not for their sake that the study is so insisted on by disciplinarians. It is insisted on for far other purposes, and with designs very foreign to that of arriving at the clearest and largest knowledge by the easiest and most direct processes. A moderate amount of drill in Euclid may be very necessary for the purpose of learning logic in a practical way, but let it be so understood and not sail under false colors. It certainly is a matter of vastly more importance, as a piece of mathematical training, to have the student of Euclid acquire the habit of discovering for himself the demonstration of new propositions than that the study of Euclid should be made a huge memoriter exercise as is usually done in college. It is one serious count in the indictment against study for the sake of discipline as its principal object, that the availability of a study for such a purpose has no necessary relation to its value as a part of human knowledge. By reason of this it has come to pass that the relative importance of Euclidian geometry as compared with other parts of mathematics has not been properly regarded in our college courses. Higher analysis is the method by which modern discoveries have been reached, based to be sure in many cases upon geometrical and mechanical ideas, but nevertheless having little in common with Euclid.

It is greatly to be desired that the study of Euclid should be preceded by exercises in practical geometry. Every instructor of geometry is aware how much those boys excel in this study who have had some practical experience in the use of carpenters' or mechanics' tools. The clear apprehension of geometrical rela-

[illegible] them, is of the first [illegible] any work which deals with [illegible]ism, or the use of draught- [illegible]metry.

[illegible]s could well be covered before [illegible]ementary parts of algebra, the [illegible]es the practical use of loga- [illegible]leas of analytical geometry. [illegible] that the training in all those [illegible]ctively modern and which must [illegible]ny with its methods, would fall [illegible]urse. It seems to be a mistake [illegible] analytical trigonometry very ex- [illegible].

[illegible] of topics of mathematical study [illegible]er of the instruction imparted in [illegible]rom that given in the preparatory [illegible]nuation of it as has been the case [illegible]me. The most successful school [illegible]very learned men. They need to [illegible] and to this end vivacity, tact in [illegible]cter, are far more important qual- [illegible] of knowledge. But in college [illegible]ainments will secure the professor [illegible]ght to expect of him. Objection may [illegible]athematical preparation which it is [illegible]e schools. The amount, however, [illegible]e in view of the large requirements [illegible] have been gradually forced upon the [illegible]sponding advance in mathematics.

[illegible] scope of mathematical instruction to [illegible]urse? The most diverse views may be [illegible]sion, yet I think a substantial agreement [illegible] of principal importance. Doubtless [illegible]portance than any other is the present [illegible]e infinitesimal calculus, including the [illegible]quations. It seems superfluous for me to [illegible]astery of this calculus, any mathematical [illegible]s hopeless, and that a knowledge of its [illegible]y facility in their employment, is abso- [illegible]nderstanding of the exact sciences. If any

single mathematical subject could be taken as a gauge of the success or lack of success in the higher mathematical instruction of our colleges, the calculus would, I think, furnish a more satisfactory test than any other. When, as often happens, our college graduates go abroad for post-graduate study in departments requiring previous mathematical training, what do they find their acquirements in this direction to amount to? I think I may say that a large proportion of them find themselves almost hopelessly lacking in the essentials of such training and not at all fitted to make proper improvement of the advantages of which they have sought to avail themselves. Our young men are unequal to the mathematical studies which those of the same age but of European academic training successfully carry. Now where does the difficulty lie? Not in any inferior talent for these studies, as I have the best of reasons for believing, but from lack of opportunity for obtaining a comprehension of the infinitesimal calculus, in which they usually find themselves almost wholly wanting. If these picked students find themselves thus deficient, it goes without saying that the knowledge others have of this subject must be meagre indeed. Calculus is not omitted, I suppose, from the scheme of study of any classical college in this country, but it is hardly too much to say that so far as any real knowledge of it is concerned it might as well be omitted from the curriculum of nearly all of them.

Several circumstances conspire to produce this state of things. On making an examination of a large number of catalogues containing the courses of study of such institutions, it is found that the text-books in use are of such very elementary and defective a character, that when the instruction is confined to what they contain, as it usually is, no sufficient knowledge of the subject can be obtained from them. They are constructed on the plan of omitting almost everything which may present any special difficulty. Even where the text-book in use is a better one, the method of instruction is wrong. After making all due allowance for the difference in methods due to the personal peculiarities of teachers, the truth still remains that, in order to impart a knowledge of this or any other difficult subject, it must be really *taught*. Now it has been in effect, assumed by those imbued with the disciplinary spirit that a knowledge of this subject could be conveyed to the student by daily recitation upon its principles and developments. I, for

one, am convinced that no explanation of its principles, however clearly made, and, I may add, however completely understood, will impart a practical knowledge of this most important method. It is as useless to attempt it, as to try to prepare an army for the battle field by a daily lecture, instead of a daily drill; or by explaining tactics instead of practising them. The one thing should be done, but the other must not be left undone. This, I think, touches the grand difficulty in our whole scheme of mathematical instruction. An attempt has been made to reverse the natural order of things in mathematical study in the same manner as has been done in that time-honored custom of trying to learn language by first studying its grammar. There is a natural method in the study of mathematics, just as truly as there is of language, and the employment of it is followed by results equally surprising in both cases. The important processes actually employed in calculus are not so very numerous nor are they especially difficult to acquire. No real use, however, can be made of its methods until these are acquired. It must often happen that the full significance of such processes is not apprehended until long after they are employed with dexterity. Certain it is that such dexterity and familiarity conduce wonderfully to their correct comprehension. Such treatises as those of Todhunter, Williamson and Boole contain invaluable lists of selected exercises from which such dexterity can be obtained. The text of such works affords very little difficulty even to students of moderate capacity provided they have acquired ready skill in the algebraic work. This ready skill is not a rare and difficult accomplishment at all:—no more so than is the ability to perform chemical analysis a rare gift. It simply needs cultivation by some one who has such ready skill himself. But this kind of work is not in accord with the disciplinary spirit and can hardly flourish where that spirit prevails.

How much the true spirit of mathematical instruction has been misconceived in classical colleges may be seen from an occurrence which was not, I am led to believe, of an unusual character. A gentleman of distinguished classical attainments and linguistic talents, now a valued professor in that department, who had spent several years abroad perfecting himself in his specialty, on returning from Europe accepted the position of tutor at Yale. On assuming the duties of that office what was his surprise and indignation at finding that the department of instruction to which

he was assigned was mathematics, and the subject algebra — a subject wholly foreign to his tastes and special requirements — one indeed which he had not touched since his freshman year. Evidently the only duty expected of him was to hear recitations from a text-book, and give marks for such recitations. The daily marking system is perhaps the most characteristic and most pernicious outward expression of the disciplinary spirit. How have the evils of that system been intensified in our larger and older colleges by the wholesale manner in which the work is done! The work of recitation and instruction can no doubt often be advantageously combined, but what is the probability that valuable instruction will be communicated during the hour to which the exercise is confined when the number of students in the recitation room is thirty, forty or even more? Not more than fifteen or twenty can in one hour's time have separate personal contact with an instructor which is of practical value. What a perversion of the purposes of the noble endowments for higher education, to expend almost the entire energy of the teaching force of the many institutions who adopt this system, in a daily effort to weigh with minutest accuracy the fidelity with which assigned tasks have been committed to memory — I am not willing to say understood! How sadly this fails to accomplish the worthiest ends of education! So entirely has memoriter recitation gained control of the educational field in our colleges and so completely has it stifled free inquiry, that there is no opportunity for a student to ask a single question of his instructor. In my college days, a question from a student during recitation was unknown, and would have been regarded by the student world as overstepping the bounds of propriety. How little opportunity there was out of recitation for questions is evident when the size of the classes is considered.

What other mathematical subjects should be included in the course of the liberal arts it is not my object at this time to attempt to decide. If we but once succeed in getting the instruction upon a healthy basis the question will decide itself in accordance with experience and the needs of science. The most diverse views may be entertained as to whether the college course can embrace analytical mechanics, or the theory of determinants (now so universally used) or whether it can omit vector and quaternion analysis. When I mention subjects so far out of the ordinary range of undergraduate study, I am aware that I shall be met with incre-

dulity as to its possibility. When, however, I find that in our small western college, graduating less than a dozen annually, we have now had for years volunteer classes pursuing all these and other subjects annually with success, I do not share in any incredulity as to its practicability or profitableness.

In conclusion, I wish to call for reform in our mathematical teaching. I call for deliverance from the imprisonment it has suffered, for removal of the bands with which it has been bound. I call for the introduction of a spirit of free inquiry. Let not all mathematical teaching be run in one narrow mould. Let it not be so conducted that he who has neither taste for the study nor special knowledge of it, stands on an equal footing as a teacher with the man of real mathematical insight. Mathematics has been termed the science of necessary conclusions. It furnishes the indispensable groundwork for the study of exact science. It fills a wide field in the intellectual needs of any people of strong intellectual powers. It awakens the interest and stimulates the open ing mind as do few studies. One study of genuine interest, ore worthy and absorbing pursuit is sufficient to drive away lethargy and stamp a manly, vigorous character upon a young man. We cannot afford to let this blade of Damascus rust in its scabbard. Now is a favorable time for revising our estimates of what can and ought to be done in this field. Higher mathematical culture has commenced a new and fruitful growth in this country in various places, but nowhere with more promise than at the Johns Hopkins University, at Baltimore, that wonderful new star in the galaxy of American Universities. To lofty ideals must be joined sound learning, great patience, and an ambition never to rest until we occupy the foremost place in intellectual achievement. Many of our younger mathematicians have won golden opinions for their abilities and zeal in foreign universities. I think we ought to form an association of the mathematicians of this country for the purpose of concerted action in improving the mathematical training in our colleges, in which the fire and enthusiasm of this young blood should be called upon to help on the cause. No learned body among us has a more vital interest in this question than the one I now have the honor of addressing. I therefore need make no apology for attempting, as I have done, to fix your attention upon those phases of it which have been suggested to me by my experience.

# PAPERS READ.

PHENOMENA OBSERVED UPON THE SOLAR SURFACE FROM 1881 TO 1884. By Rev. S. J. PERRY, Stonyhurst College Observatory, Whalley, England.

[ABSTRACT.]

THE principal subject contained in this communication was the classification of the faint evanescent markings that are always visible on the sun. The only observer who had previously made any serious study of these objects was E. L. Trouvelot whose researches at the Harvard College Observatory in 1875 were known to the author only through the few lines on the subject in Prof. Young's work on the sun. Trouvelot classed them all as "veiled solar spots," but the author of this paper has thought it more advisable to divide them into three classes.

Class 1. Ill-defined patches of a cold grayish tint, which, individually, never last for more than three minutes. They are scattered over the whole of the surface, and appear suddenly as irregular patches. The sudden appearance of many of these faint objects in the same locality and their rapid development, frequently give rise to a blurred appearance which has been so marked a feature in Dr. Janssen's magnificent solar photographs.

Class 2. Other faint spots appear at first as small, dark and fairly defined dots, and after retaining this appearance for about two minutes, suddenly spread out and cannot, at this stage of their short existence, be distinguished from spots of the first class. These are also found in every heliographic latitude and at all times, and never last more than a few minutes.

Class 3. This last class of ill-defined spots approaches much nearer to the ordinary spots than those already mentioned. They have never been seen outside the spot zones and are generally in the immediate vicinity of spot groups, but they remain indistinct throughout their whole period of visibility. They last sometimes

for a few hours but may be generally seen for two or three days. Their formation is apparently very rapid, but they disappear gradually.

This classification of the faint solar spots was followed by some remarks on the spot maximum of 1882–3; on the position of faculæ with respect to spots, offering an explanation of the apparent lagging of faculæ behind large spots; on abnormal extensions of the penumbra; on dark shadows seen in connection with faculæ; on the colors seen in spots; and on the motion observed on several occasions when the moving body remained always projected on the solar disk from its first to its last appearance.

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## Description of a model of a ruled cubic surface known as the cylindroid. By Prof. Robert S. Ball, Royal Astronomer of Ireland, Dublin, Ireland.

[ABSTRACT.]

In a work on the "Theory of Screws" published in 1876[1], I discussed the various kinematical and dynamical relations of the ruled cubic surface of the third degree which is defined by the equation.

$$z(x^2+y^2)-2mxy=0$$

This surface had been discovered by Plücker and he had, the writer is informed, made a model of it to illustrate its application in the theory of the Linear Complex. It does not however appear that Plücker had ever contemplated the significance of this surface except in the region of pure geometry. The dynamical interest of the surface is however very great as will be understood from the following enumeration of a few of its properties.

We first premise the following well-known theorems:

(1) Any movement of a rigid body can be produced by a twist about a screw (meaning by a twist, a rotation about an axis and a translation parallel thereto and equal to the product of the rotation by the pitch of the screw).

[1] Dublin, Hodges Foster & Co.

(2) Any system of forces acting on a rigid body can be expressed by a wrench on a screw (meaning by a wrench, a force along an axis and a couple in a plane perpendicular thereto, the moment of the couple being the product of the force by the pitch of the screw).

If three twists be so related that the body by the last twist is restored to the position which it had before the first, then the three screws must lie on a cylindroid and their pitches will be given by the law,

$$p = c + m \cos 2\theta$$

Where $p$ is the pitch of any screw on the cylindroid and where $c$ and $m$ are constants and $\theta$ is given by writing the cylindroid in the form,

$$\begin{cases} y = x \tan \theta \\ z = m \sin 2\theta \end{cases}$$

If three wrenches applied to a rigid body equilibrate, then the three screws must lie on a cylindroid and their pitches will be as just defined.

It follows that the composition of twists or displacements of a rigid system and the composition of wrenches follow the same laws.

This is the foundation of the Theory of Screws, which will be found fully developed in the work referred to.

The model of the surface which has been figured in the frontispiece of the "Theory of Screws" did not exhibit the nodal line which is one of the most interesting of the features in the geometrical theory. I therefore have recently availed myself of the mechanical skill of Mr. Howard Grubb to construct a model on an improved principle. This model is now submitted to the meeting.

A brass cylinder was mounted on a dividing engine and holes were drilled into it in the calculated positions. Through each of these holes a silver wire was passed to the hole diametrically opposite. These wires intersected in the axis of the cylinder and a most beautiful and interesting model is the result. The tangent cone to the surface from any point has three cuspidal edges. These are most beautifully shown and change with every varying aspect of the model.

## On a geometrical interpretation of the linear bilateral quaternion equation. By Irving Stringham, Professor of Mathematics, University of California, Berkeley, Cal.

[ABSTRACT.]

Hamilton's solution of the equation $aq + qa_1 = c$ ($a$, $a_1$ and $c$ being known constant quaternions) is

$$q = (Ka \cdot c + c \cdot a_1)\ (a_1^2 + 2a_1 Sa + aKa)^{-1}.$$

When $Sa = -Sa_1$ and $Ta = Ta_1$, this expression for $p$ becomes indeterminate, and the equation requires a different method of treatment.

I first solve the equation

$Va \cdot p + p \cdot Va_1 = O$, or $ap + p a_1 = O$. [$a = Va$ $a_1 = Va_1$.]

We have here successively

$$S(a + a_1)\ Vp = O,$$

$$Vp = x(a - a_1) + y Vaa_1,$$

that is $$p = x(a - a_1) + y Vaa_1 + Sp,$$

since by the condition of the first of these equations, $Vp$ must lie in a plane perpendicular to $(a + a_1)$. If this expression for $p$ be substituted in the equation $ap + p a_1 = O$, the part involving $x(a - a_1)$ will vanish and we shall have remaining

$$(a + a_1)\ Sp + y(a - a_1)\ Vaa_1 = O,$$

from which the value of $Sp$ is easily found. The completed expression for $p$ results in the form

$$p = x(a - a_1) - y a(a - a_1).$$

Following an interpretation first suggested to me by Professor Klein, I define, in general, every quaternion to be a directed right line in space of four dimensions. Under this interpretation, $p$, being the sum of arbitrary multiples of two fixed straight lines, evidently generates a plane (of the ordinary kind) passing through the origin.

In order to obtain the complete solution for $aq + qa_1 = c$, we have only to find any value of $\zeta$ which will satisfy the equation, and add it as a constant to the expression above found for $p$. Without discussing here the methods of obtaining such a value of $\zeta$ which would lead me into matters I cannot confine within the limits of this paper, I merely write down one of these values, viz., $\zeta = \frac{1}{2}c$, remarking that it represents geometrically the perpendicular from the origin upon the plane whose equation is $a(\quad) + (\quad)a_1 = c$.

The complete solution of this equation appears now in the form

$$q = \tfrac{1}{2} a^{-1} c + x (a - a_1) - y a (a - _1),$$

the geometrical signification of which is evident, viz., $q$ generates a plane passing through the extremity of and perpendicular to $\frac{1}{2} a^{-1} c$.

The relations of such planes to each other in four dimensional space, their intersections, conditions of parallelism, perpendicularity, etc., I shall discuss at greater length on another occasion.

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ON THE ROTATION OF A RIGID SYSTEM IN SPACE OF FOUR DIMENSIONS. By IRVING STRINGHAM, Professor of Mathematics, University of California, Berkeley, Cal.

[ABSTRACT.]

I SHALL assume the following theorem which may be easily proved; viz.: $q$ and $q_1$ may be so determined that any quaternion $p$ may be transformed into any other quaternion $p_1$, whose tensor is the same as that of $p$, by means of the operator $q(\ )q_1^{-1}$, *i. e.*, so that $qpq_1^{-1} = p_1$. The tensors of $q$ and $q_1$ may, without loss of generality, be assumed to be unity.

The object of this notice is to explain the geometrical significance of this operation, which may with propriety be called a rotation in four dimensional space, inasmuch as $p$, representing a straight line drawn from the origin to any point in the space, may, if the above theorem be true, be rotated into any other such line by means of the above operator.

If $q$ and $q_1$ be written in the forms

$$q = \lambda^{\frac{\varphi}{\pi}} = \cos\tfrac{\varphi}{2} + \lambda \sin\tfrac{\varphi}{2}$$

$$q_1 = \lambda_1^{\frac{\varphi_1}{\pi}} = \cos\tfrac{\varphi_1}{2} + \lambda_1 \sin\tfrac{\varphi_1}{2}$$

and the substitutions $\psi = \frac{\varphi + \varphi_1}{2}$, $\psi_1 = \frac{-\varphi_1}{2}$ be made, the operator under consideration will assume the form

$$q\ (\ )\ q_1^{-1} = \lambda^{\frac{\psi_1}{\pi}}\ \lambda^{\frac{\psi}{\pi}}\ (\ )\ \lambda_1^{-\frac{\psi}{\pi}}\ \lambda_1^{\frac{\psi_1}{\pi}},$$

or

$$q\ (\ )\ q_1^{-1} = s\ r\ (\ )\ r_1^{-1}\ s_1.$$

It will in other words be resolved into two constituent operators $r\ (\ )\ r_1^{-1}$, $s\ (\ )\ s_1$, in which the special relations $Sr = Sr_1$ and $Ss = Ss_1$ exist. The geometrical interpretation is made by means of these two forms.

*Taking them separately*, I observe that $r\,p\,r_1^{-1}$ may be developed in the form

$$r\,p\,r_1^{-1} = p + r\,(\lambda p - p\,\lambda_1),$$

and that if $p$ be so chosen as to satisfy the equation $\lambda p - p\,\lambda_1 = O$, no change in $p$ takes place, so that no point in the plane whose equation has just been written is disturbed by the operation $r(\ )r_1^{-1}$.

But again, $r\,p\,r_1^{-1}$ may also be developed in the form

$$r\,p\,r_1^{-1} = r^2 p - r\,(\lambda p + p\,\lambda_1).$$

If then $p$ be so chosen as to satisfy the equation $\lambda p + p\,\lambda_1 = O$, we have

$$r\,p\,r_1^{-1} = r^2 p.$$

But $r^2 p$ also satisfies the above equation whenever $p$ satisfies it, viz. $\lambda r^2 p + r^2 p - r^2(\lambda p + p\,\lambda_1) = O$, and the tensor of $r^2 p$ is the same as that of $p$ itself; $p$ in this case, therefore, is merely displaced in the plane whose equation is $\lambda p + p\,\lambda_1 = O$ and its extremity moves upon the circumference of a circle.

Now by writing $p$ in the form

$$p \quad (\mathrm{T}r \cdot p_1 + p_1\,\mathrm{T}r_1) + (\mathrm{T}r \cdot p_2 - p_2\,\mathrm{T}r_1),$$

one which it is always possible to give any quaternion, it will be found that the operator $r(\ )r_1^{-1}$ leaves the first parenthesis unchanged while the second is so changed as always to represent a line in the same plane, and its tensor evidently remains unchanged, hence, if $p$ represent any straight line whatever in space of four dimensions, its extremity will always move upon the circumference of a circle when operated upon by the symbol $r(\ )r_1^{-1}$. The [illegible] circles are in a certain sense parallel to each [illegible]. When the operator $r_1$ [illegible] upon the two parts of $p$ [illegible]

[illegible]

DESCRIPTION OF THE LEANDER McCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA. By Prof. ORMOND STONE, Director of the McCormick Observatory, University of Virginia.

[ABSTRACT.]

THE main building (Wilson Bros. & Co., of Philadelphia, architects), consists of a circular position of brick surmounted by a hemispherical dome of 45 ft. diameter, fronted by a rectangular portion 20 ft. × 30 ft. used as a computing house. The dome was built by Warner & Swasey, of Cleveland, Ohio. The running gear differs from that of Grubb, mainly in having the systems of triple wheels connected together simply by a light rod, and each system guided by a horizontal wheel before and behind, running between the turned vertical edges of the tracks of the wall plate. The frame of the dome is of steel, covered with galvanized iron and lined with painted canvas. There are three openings. No. 1 extends from the horizon to 40° altitude. No. 2 from 30° to 67°. No. 3 from 58° to 95°. Centre of No. 2 is opposite closure between Nos. 1 and 3. This system gives stability to the dome and gives opportunity for improved ventilation. The shutters are each double, the halves of each sliding by an ingenious parallel motion on horizontal tracks.

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ON THE FUNDAMENTAL FORMULA OF STATISTICAL MECHANICS, WITH APPLICATIONS TO ASTRONOMY AND THERMODYNAMICS. By Prof. J. WILLARD GIBBS of Yale College, New Haven, Conn.

[ABSTRACT.]

SUPPOSE that we have a great number of systems which consist of material points and are identical in character, but different in configuration and velocities, and in which the forces are determined by the configuration alone. Let the number of systems

in which the coördinates and velocities lie severally between the following limits, viz., between

$$\begin{aligned} &x_1 \text{ and } x_1 + dx_1, \\ &y_1 \text{ and } y_1 + dy_1, \\ &z_1 \text{ and } z_1 + dz_1, \\ &x_2 \text{ and } x_2 + dx_2, \\ &\quad \text{etc.}, \\ &\dot{x}_1 \text{ and } \dot{x}_1 + d\dot{x}_1, \\ &\dot{y}_1 \text{ and } \dot{y}_1 + d\dot{y}_1, \\ &\dot{z}_1 \text{ and } \dot{z}_1 + d\dot{z}_1, \\ &\dot{x}_2 \text{ and } \dot{x}_2 + d\dot{x}_2, \\ &\quad \text{etc.}, \end{aligned}$$

be denoted by

$$L\, dx_1\, dy_1\, dz_1\, dx_2 \text{ etc. } d\dot{x}_1\, d\dot{y}_1\, d\dot{z}_1\, d\dot{x}_2 \text{ etc.}$$

The manner in which the quantity $L$ varies with the time is given by the equation

$$\frac{dL}{dt} = -\Sigma\left[\frac{dL}{dx}\dot{x} + \frac{dL}{d\dot{x}}\ddot{x}\right],$$

where $t$, $x_1$, $y_1$, $z_1$, $x_2$, etc., $\dot{x}_1, \dot{y}_1, \dot{z}_1, \dot{x}_2$, etc., are the independent variables, and the summation relates to all the coördinates.

The object of the paper is to establish this proposition (which is not claimed as new, but which has hardly received the recognition which it deserves) and to show its applications to astronomy and thermodynamics.

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LINEAR FUNCTIONS OF POINTS, LINES AND PLANES. By Prof. E. W. HYDE, Cincinnati, Ohio.

[ABSTRACT.]

IT is shown in this paper that, if $p$, L and P represent respectively a variable point, line and plane, and if $\varphi$ be the symbol of a linear function; then $\varphi p$, $\varphi L$, $\varphi P$, have geometrical applications and uses, whose relation to trilinear, quadriplanar and tangential coördinates is analogous to that between Hamilton's geometrical development of $\varphi\rho$ and ordinary Cartesian coördinates, the elegance and conciseness of the processes being as great in the one case as in the other.

COLORS OF THE STARS. By Prof. E. C. PICKERING, Director of Harvard College Observatory, Cambridge, Mass.

[ABSTRACT.]

OBSERVATIONS of the colors of about four hundred of the brightest stars are now being made at the Harvard College Observatory. The light is analyzed by a direct vision prism, and the intensity of rays of various wave-lengths is measured by a wedge of shade glass.

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ON THE COLORS OF VARIABLE STARS. By S. C. CHANDLER, Jr., Harvard College Observatory, Cambridge, Mass.

[ABSTRACT.]

IN this paper the author gives the results of an extensive series of observations upon the colors of telescopic variable stars, made by him with the 6¼ inch Clacey equatorial at the Harvard College Observatory in 1883 and 1884, and also the inferences drawn from a discussion of them.

The observations are of two kinds: First, estimates by the decimal scale method practised by Schmidt and others; second, by a new method of the author's, by which the redness of a star's light is measured by the relative diminution of its brilliancy compared with that of a colorless star, as seen through colored glass shades.

The discussion shows that the relation pointed out by the author several years ago, — and independently by Schmidt, — between the depth of color tint and the length of the periods of variable stars is strikingly confirmed by both series of observations here given and he regards the existence of this relation as thus demonstrated. This result may be considered as of the utmost importance in its bearing on the theory of the causes of stellar variability.

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dulity as to its possibility. When, however, I find that in our small western college, graduating less than a dozen annually, we have now had for years volunteer classes pursuing all these and other subjects annually with success, I do not share in any incredulity as to its practicability or profitableness.

In conclusion, I wish to call for reform in our mathematical teaching. I call for deliverance from the imprisonment it has suffered, for removal of the bands with which it has been bound. I call for the introduction of a spirit of free inquiry. Let not all mathematical teaching be run in one narrow mould. Let it not be so conducted that he who has neither taste for the study nor special knowledge of it, stands on an equal footing as a teacher with the man of real mathematical insight. Mathematics has been termed the science of necessary conclusions. It furnishes the indispensable groundwork for the study of exact science. It fills a wide field in the intellectual needs of any people of strong intellectual powers. It awakens the interest and stimulates the open ing mind as do few studies. One study of genuine interest, one worthy and absorbing pursuit is sufficient to drive away lethargy and stamp a manly, vigorous character upon a young man. We cannot afford to let this blade of Damascus rust in its scabbard. Now is a favorable time for revising our estimates of what can and ought to be done in this field. Higher mathematical culture has commenced a new and fruitful growth in this country in various places, but nowhere with more promise than at the Johns Hopkins University, at Baltimore, that wonderful new star in the galaxy of American Universities. To lofty ideals must be joined sound learning, great patience, and an ambition never to rest until we occupy the foremost place in intellectual achievement. Many of our younger mathematicians have won golden opinions for their abilities and zeal in foreign universities. I think we ought to form an association of the mathematicians of this country for the purpose of concerted action in improving the mathematical training in our colleges, in which the fire and enthusiasm of this young blood should be called upon to help on the cause. No learned body among us has a more vital interest in this question than the one I now have the honor of addressing. I therefore need make no apology for attempting, as I have done, to fix your attention upon those phases of it which have been suggested to me by my experience.

# PAPERS READ.

PHENOMENA OBSERVED UPON THE SOLAR SURFACE FROM 1881 TO 1884. By Rev. S. J. PERRY, Stonyhurst College Observatory, Whalley, England.

[ABSTRACT.]

THE principal subject contained in this communication was the classification of the faint evanescent markings that are always visible on the sun. The only observer who had previously made any serious study of these objects was E. L. Trouvelot whose researches at the Harvard College Observatory in 1875 were known to the author only through the few lines on the subject in Prof. Young's work on the sun. Trouvelot classed them all as "veiled solar spots," but the author of this paper has thought it more advisable to divide them into three classes.

Class 1. Ill-defined patches of a cold grayish tint, which, individually, never last for more than three minutes. They are scattered over the whole of the surface, and appear suddenly as irregular patches. The sudden appearance of many of these faint objects in the same locality and their rapid development, frequently give rise to a blurred appearance which has been so marked a feature in Dr. Janssen's magnificent solar photographs.

Class 2. Other faint spots appear at first as small, dark and fairly defined dots, and after retaining this appearance for about two minutes, suddenly spread out and cannot, at this stage of their short existence, be distinguished from spots of the first class. These are also found in every heliographic latitude and at all times, and never last more than a few minutes.

Class 3. This last class of ill-defined spots approaches much nearer to the ordinary spots than those already mentioned. They have never been seen outside the spot zones and are generally in the immediate vicinity of spot groups, but they remain indistinct throughout their whole period of visibility. They last sometimes

might be made perpendicular to the axis of rotation and at a distance of about five feet from the centre of the axis. The stops are heavy plates of iron with projecting oval surfaces of tempered steel which move along this table, and which are held in position by heavy clamping screws. They are arranged for a movement of the telescope over arcs varying between 0° and 30°. With the aid of the graduated circle of the telescope it is found easy to set the stops quickly and accurately by tapping the stop-plates with a light hammer. It was found that a bichromate battery of six cells was sufficient to clamp the magnet-arm securely to the ring.

It will be at once understood that unless the ring upon which the magnet-arm rests is truly circular, the arm will rise and fall with the revolution of the telescope, thus giving rise to periodic errors proportional in amount to the deviation of the periphery of the ring from a true circle. The test of this circular form was made by means of a microscope attached to the iron bed-plate with which the movement of the arm vertically was observed and measured, a graduated polished metal plate being clamped to the arm for this examination. It was found that during one-half of the revolution of the telescope very little motion of the arm could be detected, but that during the remaining half the maximum rise of the arm amounted to about $\frac{1}{20}$ mm. As was to be expected the chief part of the disturbance occurred at those points at which the magnets passed the junction of the two halves of the ring.

It does not seem advisable to encumber this paper with the details of the observations which were made with the ring in its original form. An attempt was made to compare the 30° divisions of the graduated circle by a reference to the fixed distance between the stops, four microscopes being read for each contact, with the expectation that the effect of the error in the form of the ring could be measured by means of a microscope of high power which should measure directly the accumulated error of the arc of revolution at the contact points for each arc of 30°. It will be seen that this expectation was not realized for the summed series of errors of the 30° points of the circle.

From seven sets of observations extending from July 3 to July 15, the following relative errors were found, the polar point being taken for the origin.

| Arc. | Corrections. | Sum'd Series. | Arc. | Corrections. | Sum'd Series. |
|---|---|---|---|---|---|
| ° ° | " | " | ° ° | " | " |
| 0 — 30 | +1.38 | + 1.38 | 180 — 210 | — 2.49 | +8.00 |
| 30 — 60 | +2.83 | + 4.21 | 210 — 240 | — 1.42 | +6.58 |
| 60 — 90 | +2.92 | + 7.13 | 240 — 270 | — 2.90 | +3.68 |
| 90 — 120 | +1.41 | + 8.54 | 270 — 300 | — 3.58 | +0.10 |
| 120 — 150 | +1.73 | +10.27 | 300 — 330 | + 0.03 | +0.13 |
| 150 — 180 | +0.22 | +10.49 | 330 — 360 | + 0.13 | +0.00 |

The following are the accumulated errors at contact points from measures with microscope:

| | Corrections in division of Micrometer Screw. | Corrections in Arc. | | Corrections in division of Micrometer Screw. | Corrections in Arc. |
|---|---|---|---|---|---|
| ° ° | | | ° ° | | |
| 0 — 30 | .0 | +0.0 | 180 — 210 | +17.6 | +1.5 |
| 30 — 60 | + 1.6 | +0.1 | 210 — 240 | +11.2 | +0.9 |
| 60 — 90 | + 7.6 | +0.6 | 240 — 270 | + 4.6 | +0.4 |
| 90 — 120 | +10.6 | +0.9 | 270 — 300 | + 0.0 | +0.0 |
| 120 — 150 | +16.8 | +1.4 | 300 — 330 | — 1.2 | —0.1 |
| 150 — 180 | +18.8 | +1.2 | 330 — 360 | + 0.0 | +0.0 |

It will be seen that the general form of the two summed series is the same, but they widely differ in the maximum value. It became at once obvious from this preliminary investigation that it would be necessary to grind the circle, upon which the magnet arm rests, to an exactly circular form. This was very successfully accomplished by Mr. Clark in the following way: A slide rest carrying an emery wheel was firmly mounted nearly opposite the axis of the instrument. The motion to the emery wheel was given by means of an old-fashioned spinning wheel. The operation of grinding was conducted as follows:

One assistant turned the spinning-wheel, Mr. Clark managed the slide rest, which governed the movement of the emery wheel, while I, at one end, with the aid of an assistant stationed at the other end, gave to the telescope a nearly uniform motion in revolution. When the operation of grinding was completed, it was found that a complete revolution of the telescope could be made without the slightest trace of disturbance in the position of the magnet-arm under a microscope having twelve times the magnifying power of microscopes attached to the telescope.

Before proceeding to describe the new series of observations, it will be necessary to refer to the means employed to neutralize the momentum of the telescope produced by the shock of contact with

the stops. It was found that, on account of the disturbance produced by contact made by a hand movement of the arm, there was a liability to a maximum error of about 3″. This amount was sensibly reduced by inserting a piece of writing paper between the arm and the stop, and then completing the movement by withdrawing the paper. The next experiment was with an air-buffer attached to the stop-plates, with which the initial contact was made; but it was found that the movement against the air-spring for the remaining distance to the stop was not sufficiently uniform, although there was a decided improvement over results previously obtained. A water-buffer was then employed; the water from a cylinder attached to the stop-plates being forced by a weight-pressure through a cylinder of small diameter. With this buffer as a momentum arrester, it appears from a long series of observations for contact, that the probable error of a single contact is about 0·03″ or about one-tenth of the ordinary value for a single observation with four microscopes.

Eight sets of comparisons of the 30° divisions of the circle have already been made with the improved apparatus, with the following results:

CORRECTIONS.

| DATE. | 0°—30° | 30°—60° | 60°—90° | 90°—100° | 120°—150° | 150°—180° |
|---|---|---|---|---|---|---|
| | ″ | ″ | ″ | ″ | ″ | ″ |
| July 28, | +0.22 | +1.63 | +1.43 | −0.34 | +0.64 | +0.49 |
| " 29, | +0.07 | +1.47 | +2.39 | −0.36 | +0.51 | −0.57 |
| " 30, | −0.15 | +2.91 | +2.49 | +0.13 | +0.48 | −0.60 |
| " 31, | −1.02 | +3.00 | +2.34 | −0.79 | −0.16 | −0.38 |
| Aug. 1, | −1.38 | +2.03 | +1.35 | −0.84 | +0.60 | −0.35 |
| " 1, | −0.19 | +0.97 | +0.96 | −0.94 | +0.45 | +0.59 |
| " 4, | −1.16 | +0.61 | +0.37 | −1.10 | +0.69 | −0.29 |
| " 4, | −1.16 | +1.54 | +1.46 | −1.23 | +1.02 | −0.02 |

| DATE. | 180°—210° | 210°—240° | 240°—270° | 270°—300° | 300°—330° | 330°—360° |
|---|---|---|---|---|---|---|
| | ″ | ″ | ″ | ″ | ″ | ″ |
| July 28, | −0.72 | +0.74 | −0.73 | −1.53 | −0.85 | −0.98 |
| " 29, | −0.84 | +0.52 | −0.95 | −2.55 | +0.38 | −0.06 |
| " 30, | −2.47 | +0.10 | −1.10 | −1.87 | +0.37 | −0.43 |
| " 31, | −1.10 | +0.66 | −1.00 | −1.53 | +0.62 | −0.63 |
| Aug. 1, | −0.63 | +1.43 | −0.50 | −1.72 | −0.19 | +0.21 |
| " 1, | −0.05 | +1.36 | −0.76 | −1.74 | −0.08 | +0.40 |
| " 4, | −0.04 | +1.57 | −0.10 | −0.76 | +0.30 | −0.13 |
| " 4, | −0.42 | +1.06 | −0.28 | −1.90 | +0.07 | +0.26 |

Taking the means of the separate determinations of the 30° spaces we have:

| Spaces. | Correc-tions. | Summed Series. | Spaces. | Correc-tions. | Summed Series. |
|---|---|---|---|---|---|
| 0° — 30° | −0.06″ | −0.60″ | 180° — 210° | −0.78″ | +1.70″ |
| 30 — 60 | +1.77 | +1.17 | 210 — 240 | +0.93 | +2.63 |
| 60 — 90 | +1.60 | +2.77 | 240 — 270 | −0.68 | +1.95 |
| 90 — 120 | −0.68 | +2.09 | 270 — 300 | −1.70 | +0.25 |
| 120 — 150 | +0.53 | +2.62 | 300 — 330 | −0.08 | +0.17 |
| 150 — 180 | −0.14 | +2.48 | 330 — 360 | −0.17 | +8.00 |

It is the intention to continue the examination of the subdivisions of the circle throughout the coming year. The subdivision of the 30° spaces will be made by setting the stops for that number of subdivisions, which can be safely made at one time without danger of the introduction of errors depending on the temperature. With two assistants, one to read the 4 microscopes, and one to record, the examination of the 30° divisions can be completed in about one hour and twenty minutes.

If it shall be conclusively shown from an investigation of the present graduations of the circle that this method will give greater accuracy than former methods of investigation, it is the purpose to produce a new set of graduations just inside of the original graduations.

In conclusion it may be said that an excellent test of the method will be had when the telescope is reversed and the errors of the other circle are determined. The errors of this circle have already been determined for each single degree by comparison with a graduated metal arc of 15° with which each 15° of the circle was compared. In the complete discussion which will follow, care will be taken to eliminate any systematic errors which may appertain to the form of the ring.

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THE AVERAGE ASTEROID ORBIT AND THE ASTEROID RING. By Prof. M. W. HARRINGTON, University of Michigan, Ann Arbor, Mich.

[ABSTRACT.]

THIS paper treats the asteroid system on the principles of averages; 230 orbits are employed. If a plane be conceived perpendicular to the ecliptic and passing through the vernal and autumnal equinox, and another through the solstices, they will intersect each

orbit at four points. The mean intersection at each solstice and equinox may be considered a point in the average orbit. Solving for the orbit we get the following elements:

| | |
|---|---|
| $\pi$ | 14° 39′ |
| $\Omega$ | 113° 56′ |
| $i$ | 1° 0′ |
| $e$ | 0.0448 |
| $a$ | 2.701 |

The perihelion and nodes fall near those of Jupiter, a requirement which was otherwise deduced by Professor Newcomb more than twenty years ago. Incidentally the investigation showed (by the progressive slowing of the change in the average mean distance) that we have penetrated about through the asteroid ring.

The space occupied by the asteroid is annular and the section of the ring (by a radial plane) is elliptical, with the long axis directed toward the sun. The axes are about 2 and 1.5 in terms of the earth's mean distance from the sun. The part of this space actually occupied by the asteroids at any one time is approximately represented by the fraction $\frac{1}{5\times10^{13}}$. No grouping was recognized among the orbits.

If the asteroids all reflect light alike, Vesta has a volume of about five-twelfths of all, and the first four (Juno, Ceres, Pallas and Vesta) make nearly two-thirds of the total volume. The albedo of Vesta is probably about that of the moon. If, as this indicates, the density of the asteroids is about that of the moon, their total mass will be only one twenty-seventh that of our satellite.

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MICROMETRIC OBSERVATIONS OF JUPITER'S THIRD SATELLITE. By Prof. DAVID P. TODD, Director of Lawrence Observatory, Amherst, Mass.

[ABSTRACT.]

THE observations were made with the micrometer of the 12-inch equatorial of the Lick Observatory, Mount Hamilton, Cal. The value of one revolution of the screw of this micrometer is 14″.086.

1882, December 1, 13h., m. t.

Power 300, III = 2″.55.

Power 1,000, III = 2″.32.

Distance of Jupiter from Earth = [0.6199].

## On the course of the corrections to the heliocentric longitudes of Newcomb's tables of Uranus and Neptune.

By Prof. David P. Todd, Director of Lawrence Observatory, Amherst, Mass.

[ABSTRACT.]

The latest observations of Neptune employed by Professor Newcomb in the construction of his tables of the motion of that planet were made in December of 1864; and in his tables of Uranus, the latest observations utilized were made in September of 1872.

All the observations of right ascension of these two planets made since these dates, respectively, are in this paper collated and compared with the tables, and the equations of the errors so treated as to show the course of the corrections to the heliocentric longitudes (Newcomb) of both planets.

Also, these data combined with the results reached in *Copernicus*, Vol. III, pp. 235 and 238, give the corresponding corrections to the heliocentric longitudes (Leverrier) of both planets.

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## On the general values of the obliquity of the ecliptic, and of the precession and inclination of the equator to the invariable plane, taking into account terms of the second order.

By Prof. J. C. Adams, Cambridge Observatory, England.

[ABSTRACT.]

If we adopt the values of the precession and nutation employed by Peters in his classical work, "Numerus constans Nutationis," I find that the ratio of the sum of the masses of the earth and moon to the mass of the moon is that of 82.834 to 1, a result which differs slightly from that found by Peters from the same data.

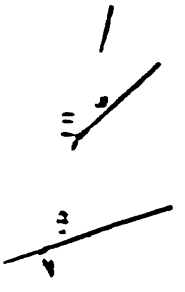
The amount of precession caused by the sun's action depends in a slight degree on the eccentricity of the earth's orbit. In order to find the precession for an indefinite period, it will be proper to employ the *mean* value of the square of this eccentricity instead of the value of this quantity at the present time.

Taking this circumstance into account and also introducing the small correction of the coëfficient of precession which depends on the square of the coëfficient of nutation, I find that if $\omega$ be the

orbit at four points. The mean intersection ... solar pre-
equinox may be considered a point in the ave... ...ented by
for the orbit we get the following elements:

| | |
|---|---|
| $\pi$ | 14° 39′ |
| $\Omega$ | 113° 56′ |
| $i$ | 1° 0′ |
| $e$ | 0.041[illegible] |
| $a$ | 2.701 |

The perihelion and nodes fall near t... ...which may be
ment which was otherwise deduced by
than twenty years ago. Incidentally
(by the progressive slowing of the cl
distance) that we have penetrated abo...



The space occupied by the asteroi...
of the ring (by a radial plane) is ell...
rected toward the sun. The axes a... ...ter, the invariable
the earth's mean distance from the ... ...ial plane.
actually occupied by the asteroids a... ...time $t$
represented by the fraction $\frac{1}{5\times10^5}$. ...ox at that time.
among the orbits. ...ent, $\theta$ and $\theta'$ the incli-
...ively to the fixed plane,
If the asteroids all reflect lig... ...ane of the ecliptic at time $t$.
about five-twelfths of all, and t... $\ldots = \ldots$
and Vesta) make nearly two-t... $\ldots = \tan\theta' \cos\varphi'$
albedo of Vesta is probably abo... ...theory of the secular variations
indicates, the density of the a... ...and $\varphi'$ may be considered as a
their total mass will be only ...ane square of which we propose to
ellite.

$\ldots = \ldots$
$\ldots = -\sin\theta \sin\theta' \cos(\varphi - \varphi')$
$\ldots = -\cos\theta \sin\theta' \cos(\varphi - \varphi')$
$\ldots = -(\varphi - \varphi')$

...and $\varphi$ are known.
...motion of the equator with reference to
...supposed for an instant to be fixed, it is

$\ldots = -\frac{1}{\sin\theta}\cos\omega \sin\omega \cos\lambda$
$\ldots = \cos\omega \sin\omega \sin\lambda$

MICROMETRIC OBSERVATIONS
Prof. DAVID P. TODD
Amherst, Mass.

THE observations were ...
equatorial of the Lick O...
value of one revolution ...
1882.
P...
Distance ...

bove for $\cos\omega$, $\sin\omega\cos\lambda$ and $\sin\omega\sin\lambda$

$\theta' + \sin\theta\tan\theta'\cos(\varphi-\varphi')]\,[\sin\theta - \cos\theta$

$\tan\theta'\cos(\varphi-\varphi')]$

$\theta' + \sin\theta\tan\theta'\cos(\varphi-\varphi')]\tan\theta'\sin(\varphi-\varphi')$

ential equations for determining $\theta$ and $\varphi$, $\theta'$ and to be already known in terms of $t$.

we may deduce the following:

$$) = \frac{dq}{dt}(\sin\theta\cos\varphi) + \frac{dp}{dt}(\sin\theta\sin\varphi).$$

ion of these equations may be readily effected by indeterminate coëfficients.

values of $p$ and $q$ to be

$$p = \Sigma\,\gamma_i \sin(g_i t + \beta_i)$$
$$q = \Sigma\,\gamma_i \cos(g_i t + \beta_i)$$

ves the successive integral values 0, 1, 2, etc., equal in the number of planets considered, and the quantities $g_i$ are known constants.

we may find that

$$+ \tfrac{1}{2}\tan h\,\Sigma\,a_i\,(a_i - 1)\,\gamma_i^2 + \tfrac{1}{2}\cot h\,\Sigma\,(a_i - \tfrac{1}{2})\,\gamma_i^2$$
$$+ \Sigma\,a_i\,\gamma_i\cos\{(k-g_i)\,t + \alpha - \beta_i\}$$
$$+ \Sigma\,a_{ii}\,(\gamma_i)^2\cos 2\{(k-g_i)\,t + \alpha - \beta_i\}$$
$$+ \Sigma\,a_{ij}\,\gamma_i\,\gamma_j\cos\{(2k - g_i - g_j)\,t + (2\alpha - \beta_i - \beta_j)\}$$
$$+ \Sigma\,a'_{ij}\,\gamma_i\,\gamma_j\cos\{(g_i - g_j)\,t + \beta_i - \beta_j\}$$

al

$$= kt + \alpha + \Sigma\,b_i\,\gamma_i\sin\{(k-g_i)\,t + \alpha - \beta_i\}$$
$$+ \Sigma\,b_{ii}\,(\gamma_i)^2\sin^2\{(k-g_i)\,t + \alpha - \beta_i\}$$
$$+ \Sigma\,b_{ij}\,\gamma_i\,\gamma_j\sin\{(2k - g_i - g_j)\,t + (2\alpha - \beta_i - \beta_j)\}$$
$$+ \Sigma\,b'_{ij}\,\gamma_i\,\gamma_j\sin\{(g_i - g_j)\,t + \beta_i - \beta_j\}$$

in which $i$ and $j$ are supposed to be different integers.

Also

$$a_i = \frac{k}{k-g_i} \text{ and therefore } a_i - 1 = \frac{g_i}{k-g_i}$$

$$a_{ii} = -\tfrac{1}{4}\,a_i\,(a_i^2 - 1)\tan h - \tfrac{1}{4}\,a_i^2\cot h$$

$$a_{ij} = -\tfrac{1}{2}\,\frac{k}{2k-g_i-g_j}\{(a_i^2 + a_j^2 - 2)\tan h + (a_i + a_j)\cot h\}$$

$$a'_{ij} = \tfrac{1}{2}\,\frac{k}{g_i - g_j}\{a_i^2 - 2\,a_i - a_j^2 + 2a_j\}\tan h + \tfrac{1}{2}\,\frac{k}{g_j - g_i}[a - a_j]\cot h$$

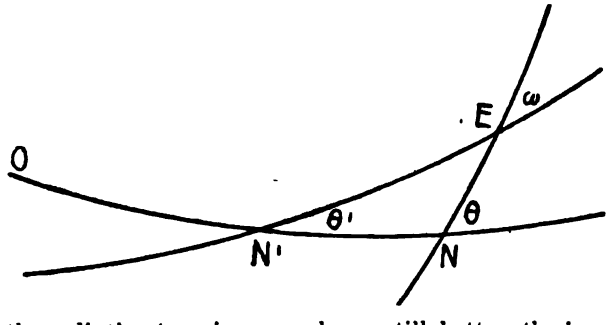
Also

obliquity of the ecliptic at any time, the rate of the luni-solar precession at that time during a Julian year, will be represented by

$$c \cos \omega$$

where $c = 54.''94625$ nearly.

Now let $ON'N$ be the fixed plane of reference which may be




either the ecliptic at a given epoch or, still better, the invariable plane of the system, or any other arbitrary fixed plane.

$N'E$ the position of the ecliptic } at any time $t$
and $NE$ that of the equator }

so that the point $E$ is the autumnal equinox at that time.

$ON = \varphi$, $ON' = \varphi'$, $O$ being a fixed point, $\theta$ and $\theta'$ the inclination of the equator and ecliptic respectively to the fixed plane, and $\omega$ the angle $N'EN$, or the obliquity of the ecliptic at time $t$.

Also let $NE = \lambda$.

Then the quantities

$$p = \tan \theta' \sin \varphi' \text{ and } q = \tan \theta' \cos \varphi'$$

are known in terms of $t$ from the theory of the secular variations of the plane of the earth's orbit, and $\theta'$ may be considered as a small quantity of the 1st order, the square of which we propose to take into account.

In the triangle $N'EN$ we have

$$\cos \omega = \cos \theta \cos \theta' + \sin \theta \sin \theta' \cos (\varphi - \varphi')$$
$$\sin \omega \cos \lambda = \sin \theta \cos \theta' - \cos \theta \sin \theta' \cos (\varphi - \varphi')$$
$$\sin \omega \sin \lambda = \sin \theta' \sin (\varphi - \varphi')$$

which give $\omega$ and $\lambda$ when $\theta$ and $\varphi$ are known.

From the instantaneous motion of the equator with reference to the ecliptic at time $t$, supposed for an instant to be fixed, it is easily seen that we have

$$\frac{d\phi}{dt} = -c \frac{1}{\sin \theta} \cos \omega \sin \omega \cos \lambda$$
$$\frac{d\theta}{dt} = c \cos \omega \sin \omega \sin \lambda$$

or, substituting from above for $\cos\omega$, $\sin\omega\cos\lambda$ and $\sin\omega\sin\lambda$

$$\frac{d\phi}{dt} = -c\frac{\cos^2\theta'}{\sin\theta}[\cos\theta + \sin\theta\tan\theta'\cos(\varphi-\varphi')][\sin\theta - \cos\theta \tan\theta'\cos(\varphi-\varphi')]$$

$$\frac{d\theta}{dt} = c\cos^2\theta'[\cos\theta + \sin\theta\tan\theta'\cos(\varphi-\varphi')]\tan\theta'\sin(\varphi-\varphi')$$

which are the differential equations for determining $\theta$ and $\varphi$, $\theta'$ and $\varphi'$ being supposed to be already known in terms of $t$.

From the above we may deduce the following:

$$\frac{d}{dt}\left(\frac{\cos\omega}{\cos\theta'}\right) = \frac{dq}{dt}(\sin\theta\cos\varphi) + \frac{dp}{dt}(\sin\theta\sin\varphi).$$

The integration of these equations may be readily effected by the method of indeterminate coëfficients.

Suppose the values of $p$ and $q$ to be

$$p = \Sigma\gamma_i\sin(g_i t + \beta_i)$$
$$q = \Sigma\gamma_i\cos(g_i t + \beta_i)$$

where $i$ takes the successive integral values 0, 1, 2, etc., equal in number to the number of planets considered, and the quantities $\gamma_i$, $g_i$ and $\beta_i$ are known constants.

Then we may find that

$$\theta = h + \tfrac{1}{2}\tan h\,\Sigma a_i(a_i-1)\gamma_i^2 + \tfrac{1}{2}\cot h\,\Sigma(a_i-\tfrac{1}{2})\gamma_i^2$$
$$+ \Sigma a_i\gamma_i\cos\{(k-g_i)t + \alpha - \beta_i\}$$
$$+ \Sigma a_{ii}(\gamma_i)^2\cos 2\{(k-g_i)t + \alpha - \beta_i\}$$
$$+ \Sigma a_{ij}\gamma_i\gamma_j\cos\{(2k-g_i-g_j)t + (2\alpha - \beta_i - \beta_j)\}$$
$$+ \Sigma a'_{ij}\gamma_i\gamma_j\cos\{(g_i-g_j)t + \beta_i - \beta_j\}$$

and

$$\varphi = kt + \alpha + \Sigma b_i\gamma_i\sin\{(k-g_i)t + \alpha - \beta_i\}$$
$$+ \Sigma b_{ii}(\gamma_i)^2\sin^2\{(k-g_i)t + \alpha - \beta_i\}$$
$$+ \Sigma b_{ij}\gamma_i\gamma_j\sin\{(2k-g_i-g_j)t + (2\alpha - \beta_i - \beta_j)\}$$
$$+ \Sigma b'_{ij}\gamma_i\gamma_j\sin\{(g_i-g_j)t + \beta_i - \beta_j\}$$

in which $i$ and $j$ are supposed to be different integers.

Also

$$a_i = \frac{k}{k-g_i} \text{ and therefore } a_i - 1 = \frac{g_i}{k-g_i}$$

$$a_{ii} = -\tfrac{1}{4}a_i(a_i^2-1)\tan h - \tfrac{1}{4}a_i^2\cot h$$

$$a_{ij} = -\tfrac{1}{2}\frac{k}{2k-g_i-g_j}\{(a_i^2+a_j^2-2)\tan h + (a_i+a_j)\cot h\}$$

$$a'_{ij} = \tfrac{1}{2}\frac{k}{g_i-g_j}\{a_i^2 - 2a_i - a_j^2 + 2a_j\}\tan h + \tfrac{1}{2}\frac{k}{g_j-g_i}[\alpha - a_j]\cot h$$

Also

$$b_i = -a_i (a_i^2 - 1) \tan h - a_i \cot h$$

$$b_{ii} = \tfrac{1}{8} a_i^2 (a_i - 1)^2 \tan^2 h + \tfrac{1}{4} a_i (a_i^2 + a_i - 1) + \tfrac{1}{2} a_i^2 \cot^2$$

$$b_{ij} = -\frac{k}{2k - g_i - g_j} a_{ij} \tan h - \tfrac{1}{2} \frac{k}{2k - g_i - g_j} [a (a_i - 1) + a_j (a_j - 1]) \tan^2 h + \tfrac{1}{2} \frac{k}{2k - g_i - g_j} [a_i^2 + a_i - 1 + a_j^2 + a_j - 1 - a_i a_j] + \frac{k}{2k - g_i - g_j} [a_i + a_j] \cot^2 h$$

$$b'_{ij} = -\frac{k}{g_i - g_j} a^1_{ij} \tan h + \tfrac{1}{2} \frac{k}{g_i - g_j} [a_i (a_i - 1) + a_j (a_j - 1)] \tan^2 h - \tfrac{1}{2} \frac{k}{g_i - g_j} [a^2_i + a^2_j + a_i a_j - 5a_i - 5a_j + 6]$$

or the value of this last coëfficient may be otherwise expressed thus

$$b'_{ij} = -\tfrac{1}{2} \frac{k}{g_i - g_j} \{(a_i - 1)(a_j - 1)(a_i + a_j) \tan^2 h + [(a_i - 1) + (a_j - 1)] [(a_i - 1) + (a_j - 1) - 1]\}$$

Also the value of $\omega$ the obliquity of the ecliptic is thus expressed in terms of the same quantities

$$\omega = h + \Sigma (a_i - 1) \gamma_i \cos \{(k - g_i) t + \alpha - \beta_i\}$$
$$\Sigma [-\tfrac{1}{4} a +_i (a_i - 1)^2 \tan h - \tfrac{1}{4} (a_i - 1)^2 \cot h] \gamma_i^2 \cos 2 \{(k - g_i) t \ \alpha - \beta +_i\}$$
$$+ \Sigma \{-\tfrac{1}{2} \frac{k}{2k - g_i - g_j} [a^2_i \ a^2 +_j - 2] \tan h - \tfrac{1}{2} \frac{k}{2k - g_i - g_j} [a_i \ a +_j] \cot h [\tfrac{1}{2} a +_i (a_i - 1) + \tfrac{1}{2} a_j (a_j - 1)] \tan h + [\tfrac{1}{2} a_i + \tfrac{1}{2} a_j - \tfrac{1}{2}] \cot h\} + \gamma_i \gamma_j \cos \{(2k - g_i - g_j) t + 2\alpha - \beta_i - \beta_j\}$$
$$-\Sigma \{\tfrac{1}{2} \frac{k}{g_i - g_j} [a^2_i - a^2_j - 2a_i + 2a_j] \tan h + \tfrac{1}{2} \frac{k}{g_i - g_j} [a_i - a_j] \cot h - [\tfrac{1}{2} a_i (a_i - 1) + \tfrac{1}{2} a_j (a_j - 1)] \tan h - [\tfrac{1}{2} a_i + \tfrac{1}{2} a_j - \tfrac{1}{2}] \cot h + \gamma_i \gamma_j \cos \{(g_i - g_j) t + \beta_i - \beta_j\}$$

Also the value of $k$ in terms of the constant $c$ which, as stated before, is known from the theory of precession is

$$k = -c \cos h \{1 - \Sigma \tfrac{1}{4} (a_i - 1)(3a_i - 5) \gamma_i^2\}$$

$h$ and $\alpha$ are the arbitrary constants which enter into the complete integrals of our equations, and they are to be determined so as to make the initial values of $\theta$ and $\varphi$, or those of $\omega$ and $\varphi$ equal to the observed values.

It is to be remarked that one of the values of $g$ is 0 and if the invariable plane of the system be taken as the fixed plane of reference, the corresponding value of $q$ will be also zero, so that the expression for $\theta$, $\varphi$ and $\omega$ will be considerably simplified by this choice of the fixed plane.

According to Stockwell's determination, in Vol. 18 of the Smithsonian Contributions, the longitude of the ascending node of the invariable plane on the ecliptic of 1850 is 106° 16′ 18″, and the inclination to the same ecliptic is 1° 35′ 18.9″

Also, as already mentioned, if we make the invariable plane of the system our plane of reference, we have for $g_0 = 0$, $\gamma_0 = 0$, and the remaining values of $g_i$ and those of $\log \gamma_i$ which correspond to them, according to Stockwell's determination, will be the following:

| | $i=1$ | $i=2$ | $i=3$ | $i=4$ | $i=5$ | $i=6$ | $i=7$ |
|---|---|---|---|---|---|---|---|
| $g_i$ | −2.″9161 | −25.″9350 | −5.″21365 | −6.″6693 | −17.″6266 | −18.″9365 | −0.″66166 |
| $\log \gamma_i$ | 7.20626 | 7.44481 | 8.01815 | 7.84525 | 7.59939 | 8.41184 | 7.12320 |

where the quantities $g_i$ are expressed in seconds and have reference to a Julian year as the unit of time, and the quantities $\gamma_i$ are expressed in the circular measure.

Hence we may find, with reference to the invariable plane, for the epoch 1850

$$\theta = 23° \ 3′ \ 42.″7$$
$$\varphi - \varphi' = 257° \ 20′ \ 21.″5$$

Now, in the figure before given, the point $N'$ is the descending node of the invariable plane on the ecliptic of 1850, so that the longitude of $N'$ is 286° 14′ 118″

Also the longitude of the point $E$ which is the autumnal equinox, is 180°. Hence $N'E = 253° \ 45′ \ 54″$

Whence we may find for 1850

$$\theta = 23° \ 3′ \ 42.″7$$

and $$\varphi - \varphi' = 257° \ 20′ \ 21.″5$$

or $$\varphi = 183° \ 34′ \ 39.″5$$

Also, according to Stockwell, the obliquity of the ecliptic in 1850 was

$$\omega = 23° \ 27′ \ 31.″0$$

Hence by repeated approximations we may find

$$h = 23° \ 18′ \ 54.″0 \text{ nearly}$$
$$a = 177° \ 25′ \ 42″ \quad ,,$$

also $$k = -50.″4614$$

whence by substitution all the terms in $\theta$, $\varphi$ and $\omega$ may be found numerically.

NOTE ON NEWTON'S THEORY OF ATMOSPHERIC REFRACTION, AND ON HIS METHOD OF FINDING THE MOTION OF THE MOON'S APOGEE. By Prof. J. C. ADAMS, Cambridge Observatory, England.

[ABSTRACT.]

Professor Adams exhibited photographs of some of the MSS. of Newton preserved in the collection lately presented to the University of Cambridge by the Earl of Portsmouth.

These papers show that Newton had thoroughly mastered the theory of atmospheric refraction and that he was acquainted with the true principles on which the motion of the moon's apogee should be found and that he had obtained a fair first approximation to the amount of that motion.

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THE NEBULÆ. By LEWIS SWIFT, Director of the Warner Observatory, Rochester, N. Y.

FOR many years it has been the opinion of astronomers that the search for new nebulæ, since it was abandoned by the Herschels, has been greatly neglected. Entertaining this view myself also, I, as soon as the 16 in. refractor of the Warner Observatory was mounted, put the idea into practice, and since then, excepting the time devoted to comet-seeking, have made their discovery and observation my special work. The success thus far attending the effort awakens the suspicion that the number of undiscovered nebulæ is very great and perhaps equalling — it may be surpassing — those already known. Only telescopes of the largest aperture, equipped with eye-pieces especially adapted for the investigation, can work successfully in this interesting field, hence these bodies fail to arouse the popular enthusiasm that the double-stars, the sun, the moon etc., inspire, all of which can be observed with smaller instruments.

In 1784, just one hundred years ago, the entire number of nebulæ known was less than 150. Their numbers, at various epochs, were as follows; in 1612 only the great nebula in Andromeda — the most conspicuous naked-eye nebula visible from our latitudes — had been observed. Forty-four years later, in 1656, another had been added, viz.: the great nebula in Orion, discovered by

that true son of genius, Huyghens. In 1614, Halley published a list of four new ones, among them being the celebrated cluster 13 Messier in Hercules, which increased the number to six. As late as the year 1732, but 152 years ago, only sixteen more had been added. In 1755 Lacaille's discoveries at the Cape of Good Hope had swelled the list to sixty-four. In 1784 Messier published a catalogue of one hundred and three clusters and nebulae, giving their places with more or less accuracy. It appears, therefore, that, previous to the advent of Sir William Herschel, the entire number of both clusters and nebulae did not, as before stated, exceed 150. In 1802, this mighty Nimrod of Astronomy who, while the world slept, hunted the sky over for the discovery of these wonderful objects, had issued catalogues of 2,500 which he had detected with instruments of his own manufacture, larger and more powerful than any previously made or considered as possible. Since that time the united labors of Sir John Herschel, Dunlop, Lord Rosse, D'Arrest, Lassell, Tempel, Stephan and others have brought up to our knowledge, as visible from all latitudes — including the 150 which I have had the good fortune to find from the Warner Observatory — about 6,700 nebulæ.

The assigned limits of this paper forbid entering largely into the many questions which suggest themselves regarding the origin and design of these immense masses of matter strewn with such lavish abundance in some regions, and so sparsely scattered in others.

The efforts of astronomers to solve this mystery, as well as those of distance from our system, their proper motion and their variation in size, shape and brightness, have thus far proved futile, and have ended only in vague and contradictory conjectures. For obvious reasons this is, and for ages to come must be, true. These masses, some of them as shapeless as the nimbus clouds, and as indeterminate as wreaths of smoke, have no points of reference, from which to measure, as have the stars and the comets with nuclei, nor sharp outlines of limb as have the sun, moon and the planets.

For one and a half years past I have been engaged in nebulæ work and I find the task of getting positions to the desired degree of exactness a difficult one indeed. The plan adopted I am not sure is the best; in fact I feel quite certain that with more experience I shall be able to improve my methods, though it must be conceded that the difficulties which beset me are well nigh in-

surmountable. In the first place, nearly all the nebulæ which have escaped the eagle-eyed astronomers who have preceded me in this field must be excessively faint. In truth I find the large majority of them the faintest objects on which human vision has ever rested. If, after discovery, I turn my eye away from the telescope without having noted its configuration with stars in the field, I sometimes experience difficulty in re-finding them although the pupil of the eye is still expanded. I work in a room absolutely dark except when reading the circles and making my records. After extinguishing the gas I am nebula-blind for two or three minutes involving a considerable loss of precious time, as, during the whole year, there are but few nights suitable for this delicate work. The eye-piece generally used is a positive periscopic by Gundlach originally made for my 4½-inch comet-seeker at the optical establishment of Bausch & Lomb, Rochester, N. Y. Finding it superior to any other when used on the 16 in. refractor, I had made for it an adapter, thereby causing it to do duty on both telescopes, it giving on the great one a power of 132, and a diameter of field of 26 minutes of arc. As no direct rays from the objective impinge on the field-lens, as is the case with a negative eye-piece, the field is dark and the faintest nebulæ are rendered visible. (In my opinion no negative eye-piece yet made is well adapted to comet or nebula seeking.) In front of the field lens are inserted two coarse hairs in the form of a cross, the intersection being exactly in the line of collimation. With a little effort I can, without artificial illumination, at all times see them, while at no time, save in the presence of moonlight, are they obtrusive. When a nebula is found, its centre is brought to the middle of the field, the driving-clock started, the telescope clamped in right ascension, the nebula bisected with the optical centre of the field in both co-ordinates, the electric sounder connected with the breakcircuit sidereal clock started, all without removing my eye from the telescope and without an assistant. After noting its size, shape, brightness, configuration with the stars in the field and, if excessively faint, the number of seconds (as counted from the sounder) it follows or precedes the nearest conspicuous star, I descend from the chair, read the circles and make the record both as to position and description. The pupil of my eye becomes greatly expanded in the dark, and the periscopic eye-piece is specially adapted for an expanded pupil, a fact of much significance to the comet-seeker, though seldom taken into consid-

eration by the optician. The discovery of new nebulæ and the finding of their approximate places are one thing, while the obtaining of positions with all the desired refinements of accuracy is another and very different matter. For the former work — their discovery — one set of appliances must answer, while for the latter another is necessary, and the two cannot be combined. When we consider the small amount in a year, of suitable weather for the finding of these exceedingly faint objects we shall see that but slow progress will be made if the observer be compelled to exchange his comet eye-piece for the micrometer, and to lose much valuable time in refinding the nebula, which probably could not be seen at all with it, selecting his comparison stars, getting its place and angle of position, finding the direction of its major axis, if elliptical, and determining various other data. To accomplish this and to make his records would require his lamp to be several times lighted, which, on each occasion, would, for at least, two minutes, entirely obliterate the nebula, presumably of unimagined faintness. And then how great would be his disappointment should he ascertain, as he probably would, that the nebula was already known. I see, therefore, no other course but to pursue the plan which I have adopted, viz.: to get as accurate positions as are attainable with the means used for their discovery, leaving to those who make a specialty of such work, to fix their places with such exactness that those who come after us may be able to determine whether they, like the stars, have not a proper motion. For aught we know the nebulæ may be no farther distant than the stars, and, consequently, their proper motion may be equally great, and ought, therefore, during the lapse of a century or two, at least in some instances, to be detected.

On July 9, 1883, I began a systematic search for new nebulæ, and, during that short night 14 were found — each one a *nova*. The next night's search revealed 7 more. Up to July 9, 1884 — one year — 150 have been discovered, of which two-thirds are in Draco, and the constellation as yet is but half explored.

Descriptions of many of the nebulæ discovered by the elder Herschel are widely at variance with their present appearance, but I doubt if, from this fact alone, we are justified in concluding that the brightness and contour of nebulæ change.

I often find nebulæ associated in pairs, and sets, and so frequently has this occurred that on the discovery of one I, invariably,

[illegible] neighborhood for another and, too often [illegible] one is found, apparently connected by [illegible] like the binary systems of the double-stars.

[illegible] searches vision is strained to its utmost ten- [illegible] wearied eye fails to equal its best efforts, I [illegible] work of comet-seeking.

[illegible] Rochester is the most cloudy region in the [illegible] The three winter months rarely afford over four, [illegible] and many of the clear nights of summer are, [illegible] useless. Since the appearance of the red- [illegible] not one exquisite night has been had. Re- [illegible] these untoward conditions, it will be apparent that [illegible] yet discovered and that the efforts put forth [illegible] Observatory have been rewarded with a fair meas- [illegible]

[illegible] some of the nebulæ in my list is inconceivable. [illegible] class III are bright objects in comparison. [illegible] and dark wires the largest telescope in the [illegible] reveal one of them, and it is very doubtful if, [illegible] and luminous wires, micrometric measures [illegible] be satisfactorily made.

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## [illegible] PAPERS READ IN SECTION A.

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[illegible] THE STUDY OF BOYLE'S LAW. By Prof. [illegible] Vassar College, Poughkeepsie, N. Y.

[illegible] By Prof. JOHN HAYWOOD, Otterbein Uni- [illegible] of Ohio.

[illegible] OF AN INTERNATIONAL ARC OF MERIDIAN [illegible] CONTINENT, FROM CAPE HORN TO THE [illegible] By PRELAWNEY SAUNDERS, Surrey, Eng-

RESULTS OF OBSERVATIONS AND EXPERIMENTS WITH AN ALMUCANTAR OF FOUR INCHES APERTURE, AT THE HARVARD COLLEGE OBSERVATORY. By S. C. CHANDLER, jr., Assistant in the Observatory, Cambridge, Mass.

THE GEODETIC WORK OF THE U. S. COAST AND GEODETIC SURVEY. By J. HOWARD GORE, Professor of Mathematics, Columbian University, Washington, D. C.

A CRITERION FOR THE REJECTION OF DOUBTFUL OBSERVATIONS. By Dr. MANSFIELD MERRIMAN, Lehigh University, Bethlehem, Pa.

HARMONIC MOTION IN STELLAR SYSTEMS.* By Prof. PLINY EARLE CHASE, Haverford College, Pennsylvania.

ON THE MEAN TEMPERATURE OF THE TWO HEMISPHERES OF THE EARTH. By Prof. H. HENNESSY, Dublin, Ireland.

ON THE CONSTITUTION OF THE EARTH AND PLANETS. By Prof. H. HENNESSY, Dublin, Ireland.

ON AN INTERNATIONAL STANDARD FOR MEASUREMENTS. By Prof. H. HENNESSY, Dublin, Ireland.

SYSTEMATIC ERRORS IN STELLAR MAGNITUDES. By Prof. E. C. PICKERING, Director of Harvard Observatory, Cambridge, Mass.

ON THE MAGNITUDE OF THE ERRORS WHICH MAY BE INTRODUCED IN THE REDUCTION OF AN OBSERVED SYSTEM OF STELLAR COÖRDINATES TO AN ASSUMED NORMAL SYSTEM BY GRAPHIC METHODS. By Prof. WM. A. ROGERS, Harvard Observatory, Cambridge, Mass.

ANALYSIS OF THE FORMULA FOR THE MOON'S LATITUDE AS AFFECTED BY THE FIGURE OF THE EARTH. By Prof. JOHN N. STOCKWELL, Cleveland, Ohio.

ON AN INDIRECT SOLUTION OF THE EQUATION

$$a = a_0 + \frac{da}{d\tau}\tau + \frac{1}{2}\frac{d_2 a}{d\tau^2}\tau^2 + \frac{1}{2}\cdot\frac{1}{3}\frac{d_3\tau}{d\tau^3}\tau^3 + \&c.$$

TO THE 6TH POWER OF THE TIME, IN WHICH $\frac{da}{d\tau}$ IS A FUNCTION OF FOUR VARIABLES. By Prof. WM. A. ROGERS, Harvard Observatory, Cambridge, Mass.

* Printed in full in Journal of Franklin Institute, Nov., 1884.

A BRIEF ACCOUNT OF SOME PRELIMINARY EXPERIMENTS IN THE CONSTRUCTION OF CLOCKS OF PRECISION. By Prof. LEONARD WALDO, Yale Observatory, New Haven, Conn.

A COLLECTION OF FORMULÆ FOR THE AREA OF A PLANE TRIANGLE. By MARCUS BAKER, U. S. Coast and Geodetic Survey, Washington, D. C.

ON THE VISIBILITY OF FAINT OBJECTS UNDER RED ILLUMINATION. By Prof. G. W. HOUGH, Director Dearborn Observatory, Chicago, Illinois.

THE PRODUCTS OF VECTORS. By Prof. SAMUEL EMERSON, University of Virginia, Va.

TEMPORARY STARS. By Prof. DANIEL KIRKWOOD, Indiana University, Bloomington, Ind.

## SECTION B.

# PHYSICS.

# ADDRESS

BY

## PROFESSOR JOHN TROWBRIDGE,

VICE PRESIDENT, SECTION B.

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## *WHAT IS ELECTRICITY?*

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THE conjunction of the meeting of the American Association with the opening of the Electrical Exposition and the sittings of the National Electrical Congress leads me to say a few words upon a question which we all ask ourselves, and to which we have hitherto had no response: "What is electricity?"

After I have concluded you will probably still ask yourselves, "What is electricity?" All I can hope to do is to make you ask yourselves the question with more humility, and a greater consciousness of ignorance; for the ignorant man, I have found, is generally sure that he knows what electricity is; and, the more learned a person is, the more he is convinced that he does not know what electricity is.

There is an advantage in sounding the depths of our ignorance, and in surveying, even from a small Mount Pisgah, the paths we have traversed, and the great promised land which lies before us. In the beginning I must express my conviction that we shall never know what electricity is, any more than we shall know what energy is. What we shall be able probably to discover is, the relationship between electricity, magnetism, light, heat, gravitation, and the attracting force which manifests itself in chemical changes. We have one great guiding principle which, like the pillar of cloud by day, and the pillar of fire by night, will conduct us, as Moses and the Israelites were once conducted, to an eminence from which we can survey the promised scientific future. That principle is the conservation of energy. To-day we see clearly that there are

not different kinds of forces; that light is not one thing and heat another; that, in truth, we should blot the word light from our physical text-books; that electricity and magnetism have their equivalents in heat, and heat in mechanical work. The ancients had a god for every great manifestation of Nature — a god of peace, a god of war, a god of the land, a god of the sea. Fifty years ago scientific men were like the ancients. There was a force attached to every phenomenon of Nature. Thus, there were the forces of electricity and magnetism, the vital forces, and the chemical forces. Now we accept treatises on mechanics which have the one word "Dynamik" for a title; and we look for a treatise on physics, which shall be entitled "Mechanical Philosophy," in which all the phenomena of radiant energy, together with the phenomena of energy, which we entitle electricity and magnetism, shall be discussed from the point of view of mechanics. It is true that Mascart and Joubert have entitled their treatise on electricity and magnetism "The Mechanical Theory of Electricity and Magnetism;" but what we are to have in the future is a treatise which will show the mechanical relations of gravitation, of so-called chemical attracting force and electrical attracting force, and the manifestations of what we call radiant energy.

When we survey the field of modern physics, we see that there is a marked tendency to simplify our conceptions. The question is sometimes asked, How shall the man of the future be able to make any advance, since it now takes one until middle age to gain familiarity with the vortex theories, with quaternions, and the more or less complicated mathematical analysis which characterizes our mechanical theory of electricity to-day? It is evident that much of our complicated scaffolding is to be taken down, and the student of electricity in the future will start with, perhaps, the laws of vortices as axioms, just as the student in physics to-day starts with the truth that the energy which we receive from the sun does not exist either as light or heat in the space between us and the sun, but may be electro-magnetic, or even in an unsuspected form; and that light and heat are merely manifestations of waves of energy differing only in length.

We have reduced our knowledge of electricity and magnetism to what may be called a mechanical system, so that, in a large number of cases, we can calculate beforehand what will take place, and we are under no necessity of trying actual experiments.

Thus, a portion of our knowledge of electro-magnetism is very much in the condition of our knowledge of what may be called geometrical astronomy, in distinction to physical astronomy. We can calculate what will take place with small errors, which arise merely from the faults of observation, and not from a want of knowledge of conditions, or from the errors of a defective theory. It is probable, for instance, that the correct form of a dynamo-machine for producing the electric light can be calculated, and the plans drawn with as much certainty as the diagrams of a steam-engine are constructed. There is a department of electricity corresponding, perhaps, to hydraulics, in which the electrical engineer can find full employment in subjecting perfectly definite conditions to exact calculation. We can congratulate ourselves, therefore, in having a large amount of systematic knowledge in electricity and we see clearly how to increase this systematic knowledge; for we have discovered that a man, to become an electrician, can not expect to master the subject of electricity, who has not made himself familiar with thermo-dynamics, with analytical mechanics, and with all the topics now embraced under the comprehensive title of physics.

Some may think that an electrician is a narrow specialist. I can only invite such persons to engage in the study of "What is electricity?"

In standing upon our scientific Mount Pisgah, we can survey the beaten roads by which we have advanced, and can see partially what has been good and what has been bad in the theories which have stood in the place of the leaders of the Israelites and have conducted us thus far. Out of all the theories—the two-fluid theory, the one-fluid, or Franklin theory, and the various molecular theories—not one remains to-day under the guidance of which we are ready to march onward. The two-fluid theory serves merely to fix the ideas of the student whose mind is new to the subject of electricity. I think I can safely affirm that no scientific man of the present believes that there is even one electric fluid, to say nothing of the existence of two. We have discovered that we can not speak of the velocity of electricity. We do not know whether the rate of propagation of what we call an electrical impulse is infinitely slow or infinitely fast. We do not know whether what we call the electrical current in a conductor is due to molecular motions infinitely faster than those of outlying molecules, or whether

there is a sudden comparative cessation of molecular motions in the wire through which the current manifests itself, compared with the molecular motions outside the wire, for this might produce the electrical phenomena we observe. We do not know whether any molecular motion is concerned in the manifestation of energy, which we call electrical. All that we can truly say is, we have a healthy distrust of our theories, and an abiding faith in that pillar of cloud by day and the pillar of fire by night — the doctrine of the conservation of energy.

Having thus outlined the present condition of our knowledge, and of our comprehension of the bearing and tendencies of physical science, let us strive, with the most powerful instruments we have, to survey the promised land which is undoubtedly to be the possession of those who come after us. It is one thing to become familiar with all the applications of the mechanical theory of electricity, and another to make an advance in the subject so that we can see the relations of electrical and magnetic attraction to the attraction of gravitation and to what we call chemical attraction. To this possible relationship I wish to call your attention to-day.

I am forced to believe that the new advances in our knowledge of electrical manifestations are to come from a true conception of the universality of electrical manifestations, and from our advance in the study of molecular physics. Picture to yourselves the position of an investigator in this world. A person on the moon could only conceive of this audience as a molecule made up of many atoms. He could not measure the energy you manifest by moving about — the heat energy — the electrical energy due to the friction of your envelopes. Indeed, he could only suppose your existence, just as we imagine the existence of a molecule of a crystal. Now, the distances we force molecules apart by many of our chemical processes seem extremely small to us; but how immense they really are compared with the distances apart of the atoms! Is it not as if we should take a stone from the moon or from Venus and place it upon the earth in the time of one second? You can imagine, from the familiar spectacle of a meteor, the heat and the electricity that would result. Yet, in respect to relative distances, do we not do something similar when we break a crystal or pour acid upon a metal, or strike a dynamite-cartridge? We are infin-

itely small ourselves compared with the great universe about us; yet our task is to comprehend the motions of aggregations of atoms infinitely smaller than that aggregation which we call man.

When we break a crystal mechanically, we have a development of electricity. When we heat certain crystals—tourmaline, for example—besides the strain among the molecules of the crystal which is produced by the increased rates of vibration, we have a difference of electrical potential. When we let an acid fall from the surface of a metal, the metal takes one state of electrification and the drop of acid the other— in other words, we produce a difference of electrical potential. On the other hand, a difference of electrical potential modifies the aggregation of molecules. The experiments of Lippman are well known to you. He has constructed an electrometer, and even an electrical machine, which depend upon the principle that the superficial energy of a surface of mercury covered with acidulated water is modified when a difference of electrical potential is produced at the limiting surfaces. I have lately noticed a striking illustration of the modification of superficial energy by a difference of electrical potential. The experiment can be performed in this way: fill the lower part of a glass jar with clean mercury, pour a saturated solution of common salt upon the mercury, hang in the salt solution a carbon plate, and connect this plate with a battery of four or five Bunsen cells; and, on connecting an iron wire with the other pole of the battery, touch the surface of the mercury. An amalgam will be speedily formed and chlorine gas given off. After a slight film of this amalgam has been formed on the mercury, remove the iron wire, and then immerse it slowly in salt-and-water. Even at a distance of six inches from the mercury, and far below the carbon electrode, the surface of mercury will be disturbed by the difference of electrical potential, and a commotion, which might be called an electrical storm, will be observed upon its surface. Now, these manifestations of what is called superficial energy— that is, the energy manifested at the surface of separation of any two media, and the effect of electricity upon this superficial energy — afford, it seems to me, much food for thought. There have always been two parties in electricity — one which maintains that electricity is due to the contact of dissimilar substances, and the other which believes that the source of electrical action must be sought in chemical action. Thus, according to one party, the action of an

ordinary voltaic cell is due to the contact, for instance, of zinc with copper, the acid or solution of the cell merely acting as the connecting link between the two. According to the other it is to the difference of chemical action on the two metals of the connecting liquid that we must attribute the rise and continuance of the electrical current. It has always seemed to me that these two parties are like the knights in the story, who stood facing opposite sides of a shield, each seeing but one side, one protesting that the shield was silver and the other that it was gold, whereas it was both silver and gold.

The electro-motive force of a voltaic cell is undoubtedly due to the intrinsic superficial manifestation of energy. When two dissimilar metals are placed in connection with each other, either directly or through the medium of a conducting liquid, the chemical action of the liquid brings new surfaces of the metals constantly in contact. Moreover, we have the difference of superficial energy between the liquid and the two metals. So that our expression for electro-motive force is far from being a simple one; it contains the sum of the several modifications of superficial energy at the surfaces of the two metals, and at the two boundaries of the liquid and the metals.

Let us turn now to the subject of thermo-electricity. Here we have again a development of electro-motive force by the mere contact of two metals, when the junctions of the metals are at different temperatures. There is no connecting liquid here, but the surface of one metal rests directly upon that of the other. The electrical current that arises is due to the difference of superficial energy manifested at the surfaces of the two junctions. We know that the action is on the surface, for the dimensions of the junctions do not affect the electro-motive force. Suppose that we should make the metals so thin that an ultimate molecule of iron should rest against an ultimate molecule of copper. Should we not arrive at a limit, at a definite temperature of the conversion of molecular vibration into electrical energy and also, when our theory is perfected, of the number of molecules along a linear line of copper against a linear line of zinc which can produce a current of electricity of a given strength? I have often thought that the jostling, so to speak, of these ultimate molecules of two metals at definite temperatures might form a scientific unit of electro-motive force in the future science of physical chemistry. Look at the

great field for investigation there is in the measurement of what we call electro-motive force, both in voltaic electricity and in thermo-electricity. The astronomer measures the positions of the stars and their light, and tabulates the enormous volumes of results from year to year, in order to ascertain some great law or laws of the possible changes of the entire stellar universe — some sweeping onward through space. Is it not fully as important that, in our physical laboratories, we should organize our routine work, and provide some great generalizer, like Sir Isaac Newton, with sufficient data of electro-motive force, or, as I prefer to call it, the relations of superficial energy, in order that the relations between this energy and the ultimate motions of the molecular worlds may become better known to us?

When the world was evolved from the first nebulous stage, a portion of the atoms remained more or less free in the gaseous state, another portion became more or less limited in organic forms, and another portion were tightly compressed into solids more or less elastic. This elasticity is thought by some to be an evidence of very rapid motion through all these various aggregations of matter — or shall we say different manifestations of motion? for some also believe that our ideas of matter result merely from a perception of motion. Shall we affirm that there is some relation between elasticity and electricity? I do not think that we are prepared to do so, for some elastic bodies are good conductors and some are poor conductors of electricity. We can see dimly, however, that there is a great field in molecular physics, in which elasticity and superficial energy and difference of electrical potential shall be treated together.

I have tried various experiments upon the electro-motive force of alloys. By means of an alloy we can apparently modify the superficial energy at the surface of a solid. Thus, an alloy with a parent metal will give a varying electro-motive force. If we could be sure that an alloy is always a definite chemical composition, and not a more or less mechanical admixture, it seems as if we could get closer to the seat of electro-motive force by a number of quantitative measurements. Unfortunately, the physical nature of alloys is not definitely known, and there is little coherence or regularity in our measurements of their electro-motive force. Still, there is a great field in the study of the electro-motive force of alloys. We can modify the superficial energy of met-

als, not only by melting metals together, but also by grinding them to a very fine powder, and compressing them again by powerful means into solids more or less elastic, and then examining their superficial energy, which is manifested as electro-motive force. I am still engaged upon researches of this nature, and, if the work is not brilliant, I hope that it will result in the accumulation of data for future generalization.

We cannot treat the manifestation of electro-motive force in the voltaic cell apart from the manifestation of electro-motive force in the differently heated junctions of a thermo-electric junction. In both cases there is a difference of manifestation of superficial energy; and in thermo-electricity we can also modify this energy by making alloys. The subject of thermo-electricity has been eclipsed by the magnificent development of the dynamo-electric machine, but we may return to thermo-electricity as a practical source of electricity. I have been lately occupied in endeavoring to modify the difference of potential of two thermo-electric junctions, by raising one junction to a very high temperature under great pressure; for it is well known that the melting-point of metals is raised by great pressure. If the metal still remains in the solid state under great temperature and great pressure, can we not greatly increase the electro-motive force which results from the difference of superficial energy manifested at the two junctions?

When an electrical current is passed through two thermo-electric junctions, it cools the hot one and heats the cool one. Moreover, you are well acquainted with Thomson's discovery that a current of electricity, in passing through a metal, carries heat, so to speak, with it — in one direction in iron and in another in copper. Do we not see here a connection between the manifestation of superficial energy in liquids and the effect of a difference of potential upon it, and the manifestations of thermo-electro-motive force and the effect of differences of electrical potential? It is curious and suggestive that, in applying the reasoning of Carnot's cycle to the effect of a difference of electrical potential on the superficial energy at the surface of separation of two liquids, one is led to the equations which express in thermo-dynamics the Peltier and Thomson effects.

In thus looking for the seat and origin of electrical action, how much have we discovered? It is evident that our knowledge of electricity will increase with our knowledge of molecular action,

and our knowledge of molecular action with that which we call attractive force. It is somewhat strange that, although we are so curious in regard to electricity, we seldom reflect that gravitation is as great a mystery as electrical attraction. What is this force which acts instantly through space, and which holds our entire solar system together? We know only its simple law — that it attracts bodies directly as their masses and inversely as the square of their distance; but we do not know what relation it bears to electrical force or magnetic force. Here is a field in which we are to push back our boundary of electrical knowledge. I will not call it electrical knowledge, but rather our knowledge of the great doctrine of the conservation of energy. What is the relation between electricity, magnetism, and gravitation, and what we call the chemical force of attraction? It seems to me that this is the question which we must strive to answer; but, when this question is answered, shall we not be as far as ever from the answer to the question, "What is electricity?"

The question of the connection between electricity and gravitation dwelt much in Faraday's thoughts. It is interesting to recall the experiments which he instituted to discover if there is any connection between these great manifestations of force. In his first experiment he suspended vertically an electro-magnet, which was connected with a galvanometer, and let various non-magnetic bodies, such as brass bodies, pieces of stone and crystals, fall through the centre of this electro-magnet, thinking that there might possibly be a reaction from the influence of gravitating force on the falling body which would be manifested as an electrical current. He did not, however, obtain the slightest electrical disturbance which might not have been caused by simple electrical induction. He then arranged a somewhat complicated piece of apparatus by means of which a body could be moved alternately with the direction of gravitation and against it, and the terminals of a galvanometer were so connected that the intermittent effects, if they existed, could be integrated or summed up. He failed, however, to find the slightest relation between gravitation and electricity, and he closes his account of his experiments with these words: "Here end my trials for the present. The results are negative. They do not shake my strong feeling of the existence of a relation between gravity and electricity, though they give no proof that such a relation exists."

Since Faraday's time no connection or relation has been found except in the similarity of the law of inverse squares. I have often reflected upon these experiments of Faraday, and have asked myself, Was the direction in which he experimented the true direction to look for a possible relation; and can not the refined instruments and methods of the electrical science of the present aid us in more promising lines of research? Should we not expect that, when two balls of copper, for instance, are suddenly removed from each other, a difference of electrical potential should manifest itself, and that the electrical force thus developed should be opposed to our endeavor to overcome the attractive force between the two masses of copper? Moreover, when we force the copper balls together, should we not expect that an electrical charge should be developed of such a nature as to oppose our motion? And thus in these mutual relations, which are apparently consistent with the doctrine of the conservation of energy, should we not expect to find the relation which we are in search of? Our experiment, therefore, would have to be conducted in this way: We should carefully insulate our two copper masses, estimate the effects that would be due in any way to cutting the magnetic lines of force of the earth, and then with a delicate electrometer, the masses having been placed in a vacuum to get rid of the effect of friction of the air, we should proceed to test their electrical relations. This experiment also gives negative results, but may we not try it under better conditions than I have been able to devise? If we could prove that whenever we disturb the relative position of bodies, or break up the state of aggregation of particles, we create a difference of electrical potential, and, moreover, if we could discover that the work that this electrical potential can perform, together with the heat that is developed by the process, is the complete work that is done on the system against attractive force, whether expressed in gravitation attractive force, or as so-called chemical attractive force, we should greatly extend our vision of the relation of natural phenomena. In thus pursuing the line of argument of my address, I venture to state an hypothetical law which it seems to me is at least plausible in the present state of electrical science, and may serve as a scaffolding to be taken down when experiment shall have properly proportioned the edifice.

This hypothetical law I should state as follows: "Whenever the

force of attraction between masses or molecules is modified in any way, a difference of electrical potential results."

In what I may therefore call the physical chemistry of the future, may we not expect that in the reactions we must express the equivalent of the difference of electrical potential in the summation of the entire work which is done? I can make my meaning clearer by referring to an experiment of Hirn by which he obtained a fair value for the mechanical equivalent of heat. In principle it is this: A heavy weight falls upon a lead vessel which contains a given amount of water at a definite temperature. The lead vessel suffers compression by the blow, and the water is raised in temperature. It is found, on properly estimating the amount of heat taken up by the lead and the loss radiated during the experiment, that the heat produced by the blow is the equivalent of its mechanical work. Suppose now that the vessel containing the water should be made of two metals of about the same specific heat or capacity for absorbing heat, and suppose that wires should connect the two different metallic portions with a similar vessel containing water. We should have here two thermo-electric junctions at the same temperature. When the weight falls upon one junction and heats it with its contained water, we have not only the heated water but also an electrical current; it is evident, therefore, that we should be able to heat the water more when the wire between the two vessels is cut, than when there is a metallic circuit between them, for a part of the energy of the falling weight has become converted into an electrical current. At the terminals of the cut wires there is a difference of electrical potential created for an instant, which, however, instantly disappears. What is the equivalent of this difference of potential? Is it not in the closed circuits through the masses of the metals, a part of which, it is true, becomes sensible heat, but another portion may become latent heat or do internal work among the molecules?

Moreover, is it not reasonable to suppose that certain anomalies which we now find in the determinations of specific heats of complicated aggregation of molecules are due to our failure to estimate the electrical equivalent of the movements and interchanges of the molecules? Let us take, again, the case of friction between two pieces of wood: is it not possible that the friction is the electrical attraction which results from the endeavor to move the adjoining particles of wood in the two pieces asunder? Let us remember, in

our endeavor to connect the phenomenon of superficial energy with electrical manifestations, that the friction between two surfaces is modified by keeping these surfaces at a difference of electrical potential. In Edison's motophone, by means of which the voice of one speaking in New York could be made audible to this audience, we see this exemplified in a very striking manner. A platinum point connected with one pole of a battery rubs upon a revolving cylinder of chalk, which is simply moistened with water and is connected with the opposite pole of the battery. The friction between the two is modified in unison with the changes in electrical potential of the battery; and a diaphragm in connection with the platinum point responds to these changes in the friction, and therefore to a transmitter placed anywhere in the electrical circuit.

My own studies have been chiefly in the direction of thermo-electricity, and in the subject of the electrical aspect of what we call superficial energy. I think there is a great field here — in which a large crop of negative results can be reaped — but these negative results I cannot regard entirely as thistles. I have tried the following experiment, on the hypothesis that an electrical difference of potential in changing the relations of molecules might modify the heat that is radiated from a surface. I have endeavored to discover whether an electrical current first cools a conductor before it heats it, as we might expect if the molecules being restrained in any way could not radiate as much energy into space as they could under the same difference of temperature, when not submitted to the action of an electrical difference of potential. I have reaped only a thistle so far from this investigation, but I shall continue it. I have deposited copper in the magnetic field and outside the magnetic field, and have endeavored to ascertain the thermo-electric relations of these layers of copper, and have apparently discovered — I say apparently, for such experiments require a large number of trials, and I have made thus far only a limited number — that there is a difference of superficial energy between the surface in which the molecules of copper have been subjected to a strong attractive force while they were being deposited, and those molecules which have been only under the influence of ordinary gravitation force.

The experiments which I have tried have continually deepened in me the belief that any change in the state of aggregation of particles — in other words, any change which results in a modification

of attracting force — whether gravitative or the commonly called chemical attracting forces, results in an electrical potential; and, conversely, that the passage of electricity through any medium produces a change of aggregation of the molecules and atoms. Professor Schuster, in a late number of "Nature" (July 3, 1884, page 230), gives some of the results of his recent investigation of gases subjected to electrical discharges, and believes himself justified in making the following hypothesis: "In a gas the passage of electricity from one molecule to another is always accompanied by an interchange of the atoms composing the molecule; the molecules are always broken up at the negative pole," and in his comments upon this law he remarks that a molecule of mercury consists of a single atom; but mercury has a very brilliant spectrum: this would seem to militate against the hypothesis. On the other hand, if an essential part of the glow discharge is due to the breaking up of the molecules, we might expect mercury-vapor to present other and much simpler phenomena than other vapors. This is the case, for if mercury-vapor is sufficiently free from air, the electrical discharge through it shows no negative glow, no dark spaces, and no stratifications. In reflecting upon experiments of this nature, cannot we believe that, if we could systematically break up the arrangement of the atoms in the molecules of any substance, we could produce a difference of electrical potential? Our instrumental means are probably too coarse to enable us to follow the track of such splitting of the molecules. We are like blind men in a great field of energy striving to ascertain the configuration about us with only three senses — the galvanometer sense, the electrometer sense, and the voltameter sense. Suppose you add to the equipment of such blind men a magnetic sense, or an attractive-force sense. Suppose such a blind man could perceive the equivalence of our thoughts in electrical and magnetic relations, as we now see a manifestation of equivalence of mechanical work when a lighthouse lamp bursts upon our sight. Suppose such a person could become sensible of every change among atoms and molecules. Suppose that the quick passing of what we call life from the body into another shape or state of existence should be sensible as a reaction in electrical and magnetic effects. Such a person could then see the quick ebb and flow and interchanges of attractive forces as we now see the play of colors. Have you ever reflected that we may possibly have some day an electrical spectrum — perhaps I should call it an attracting-force spectrum — in

which the electro-magnetic manifestations of energy shall be spread out and differentiated, just as that part of the energy which we receive from the sun and which we call light and heat is now dispersed in the visible solar spectrum? We regard to-day the manifestations of the different color of bodies — the tints of the objects in the room — as the visible expression of the great law of conservation of energy. The energy which we have received from the sun is making interchanges and is modified by the different molecular structure of the different objects. Thus, a red body has absorbed, so to speak, certain wave-lengths of energy, and has transmitted or reflected back only the red or long waves of energy. The rest of the energy has been devoted to molecular work which does not appeal to us as light or even in certain cases as heat. If we suppose that radiant energy is electro-magnetic, cannot we suppose that it is absorbed more readily by some substances than by others, that its energy is transformed so that with the proper sense we could perceive what might be called electrical color; or, in other words, have an evidence of other transformations of radiant energy other than that which appeals to us as light and color?

I have thus far conducted you over a field that, in comparison with what lies before us, seems indeed barren and churlish of results. Have we, then, nothing upon which we can congratulate ourselves? I can only reply by pointing to the rich practical results which you can see in the fine electrical exposition which we owe to the energy and liberality of the citizens of Philadelphia. Although we must glory in this exposition, it is the duty of the idealist to point out the way to greater progress and to greater intellectual grasp.

Perhaps we have arrived at that stage in our study of electricity where our instruments are too coarse to enable us to extend our investigations. Yet how delicate and efficient they are! Compare the instruments employed by Franklin, and even by Faraday, with those which are in constant use to-day in our physical laboratories. Franklin, by the utmost effort of his imagination, could not conceive, probably, of a mirror-galvanometer that can detect the electrical action of a drop of distilled water on two so-called chemically pure platinum plates, or of a machine that can develop from the feeble magnetism of the earth a current sufficiently strong to light the city of Philadelphia. Let him who wanders among the historical physical instruments of many of our college collections stand before the immense frictional electrical machine of Franklin's day, or gaze

upon the rude electrometers and galvanometers of that time, and contrast Franklin's machine with the small Toepler-Holtz electrical machine which with a tenth of the size gives a spark ten times as strong as Franklin's; or the electrometers and galvanometers of Faraday with the mirror-galvanometers and electrometers of Sir William Thomson. Yet, at the same time, let such an observer think of the possibilities of the next fifty years, for the advance of science is not in a simple proportion to the time, and the next fifty years will probably see a far greater advance than the one hundred years since the date of Franklin's electrical work has seen. Is not the state of our imagination like that of the shepherd-boy who lies upon his back, looking up at the stars of heaven, and trying to imagine what is beyond the stars? The only conclusion is that there is something far more than we have ever beheld. Is it not the physicist of the future to have instruments delicate enough to measure the heat equivalent of the red and the yellow, the blue and the violet rays of energy? — instruments delicate enough to discover beats of light as we now discover those of sound — an apparatus which will measure the difference of electrical potential produced by the breaking up of composite grouping of molecules? The photographer of to-day speaks, in common language, of handicapping molecules by mixing gums with his bromide of silver, in order that their rate of vibration may be effected by the long waves of energy. Shall we not have the means of obtaining the mechanical equivalent of such handicapped vibrations? Or, turning to practical science, let us reflect upon the modern transmitter and the telephone, and contrast these instruments with the rude, so-called lover's telephone, which consists of two disks connected by a string or wire. What an almost immeasurable advance we see here! Would it not have been as difficult for Franklin to conceive of the electrical transmission of speech as for the shepherd-boy to conceive of other stars as far beyond the visible stars as the visible stars are from the earth?

Yes, we have advanced; but you will perceive that I have not answered the question, which filled the mind of Franklin, and which fills men's minds to-day, "What is electricity?" If I have succeeded in being suggestive, and in starting trains of thought in your minds which may enlighten us all upon this great question, I have indeed been fortunate.

# PAPERS READ.

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ON THE FRITTS SELENIUM CELLS AND BATTERIES. By C. E. FRITTS, New York, N. Y.

IN all previous cells, so far as I am aware, the two portions or parts of the selenium, at which the current enters and leaves it, have been in substantially the same electrical state or condition. Furthermore, the paths of the current and of the light have been transverse to each other, so that the two forces partially neutralize each other in their action upon the selenium. Lastly, the current flows through not only the surface layer which is acted upon by the light, but also through the portion which is underneath and not affected thereby, and which therefore detracts from the actual effect of the light upon the selenium at the surface.

My form of cell is a radical departure from all previous methods of employing selenium, in all of these respects. In the first place, I form the selenium in very thin plates, and polarize them, so that the opposite faces have different electrical states or properties. This I do by melting it upon a plate of metal with which it will form a sort of chemical combination, sufficient, at least, to cause the selenium to adhere and make a good electrical connection with it. The other surface of the selenium is not so united or combined, but is left in a free state, and a conductor is subsequently applied over it by simple contact or pressure.

During the process of melting and crystallizing, the selenium is compressed between the metal plate upon which it is melted and another plate of steel or other substance with which it will not combine. Thus by the simultaneous application and action of heat, pressure, chemical affinity and crystallization, it is formed into a sheet of granular selenium, uniformly polarized throughout, and having its two surfaces in opposite phases as regards its molecular arrangement. The non-adherent plate being removed after the cell has become cool, I then cover that surface with a *transparent conductor of electricity*, which may be a thin film of gold leaf. Platinum, silver, or other suitable material may also be employed. The whole surface of the selenium is therefore covered with a good

electrical conductor, yet is practically bare to the light, which passes through the conductor to the selenium underneath. My standard size of cell has about two by two and a half inches of surface, with a thickness of $\frac{1}{1000}$ to $\frac{5}{1000}$ inch of selenium. But the cells can, of course, be made of any size or form. A great advantage of this arrangement consists in the fact that it enables me to apply the current and the light to the selenium in the same plane or general direction, instead of transversely to each other as heretofore done, so that I can cause the two influences to either coincide in direction and action, or to act upon opposite faces of the selenium and oppose each other, according to the effect desired.

By virtue of the process and arrangement described, my cells have a number of remarkable properties, among which are the following:

1. *Their sensitiveness to light* is much greater than ever before known. The most sensitive cell ever produced, previous to my investigations, was one made by Dr. Werner Siemens, which was 14.8 times as conductive in sunlight as in dark. In table A, I give results obtained from a number of my cells.

TABLE A.

SENSITIVENESS TO LIGHT.

| Selenium cell. | Battery power. | Resistance in dark. | Resistance in sunlight. | Ratio. |
|---|---|---|---|---|
| No. 22 | 5 elements | 39,000 ohms. | 340 ohms | 114 to 1 |
| " 23[1] | 5 " | 14,000 " | 170 " | 82.3 " " |
| " 24[2] | 5 " | 648,000 " | 2,400 " | 270 " " |
| " 25[1] | 5 " | 180,000 " | 930 " | 196.5 " " |
| " 26[1] | 5 " | 135,000 " | 710 " | 190 " " |
| " 107 | 5 " | 118,000 " | 740 " | 159 " " |
| " 108 | 5 " | 200,000 " | 900 " | 222 " " |
| " 122 | 5 " | 56,000 " | 220 " | 254.5 " " |
| " 129[1] | 5 " | 200,000 " | 940 " | 212 " " |
| " 137 | 5 " | 108,000 " | 320 " | 337.5 " " |

It will be observed that I have produced one cell which was

[1] Cells No. 23 and No. 129 are now in possession of Prof. W. Grylls Adams, of King's College, London; Dr. Werner Siemens has No. 25, and Prof. George F. Barker, of Philadelphia, has No. 26.

[2] No. 24 was measured with a bridge multiplier of 6 to 1.

337.5 times as conductive in hazy sunlight as in dark. The tremendous change of resistance involved in the expression "337.5 times" may perhaps be more fully realized by saying that 99.704 *per cent* of the resistance had disappeared temporarily, under the joint action of light and electricity, so that there remained *less than* $\frac{3}{10}$ *of* 1 *per cent* of the original resistance of the selenium in dark.

In order to obtain these high results, the cells must be protected from light when not in use. The resistance is first measured while the cell is still in total darkness. It is then exposed to sunlight and again measured. It is also necessary to send the current in at the gold electrode or face, as the cell is much less sensitive to light when the light acts upon one surface of the selenium and the current enters at the opposite surface. When the two influences, the light and the current, act through the gold, in conjunction, their forces are united; and, as every atom of the selenium is affected by the light, owing to the extreme thinness of the plate, we have the full effect shown in the measurements.

Cells which are sensitive to light improve by being used daily, and their sensitiveness becomes less if they are laid aside and not used for a considerable length of time, especially if allowed to become overheated. They should be kept cool, and exposed to light frequently, whether they are used or not.

*Mode of measuring cells.* So great is the sensitiveness of these cells to external influences, that it is necessary to adopt some particular system in measuring their resistance and to adhere strictly to that system, as every change in the method of measurement produces a difference in the result and the different measurements would not be comparable with each other. The reason for this will be explained presently.

The system I have adopted is the Wheatstone's bridge arrangement, with equal sides, never using multipliers except for some experimental purpose. In each multiplier wire I have 500 ohms resistance. When the bridge is balanced, one-half of the current flows through the cell and acts upon the selenium. Between the bridge and the cell is a reversing switch, so that the current can be reversed through the cell without changing its course through the bridge. A Bradley tangent galvanometer is used, employing the coil of 160 ohms resistance. The Leclanché battery is exclusively used in measurements for comparison.

2. *The kind of battery employed* has a marked effect upon the

sensitiveness to light, which is largely reduced or entirely destroyed when the bichromate battery is used. The same cells again become extremely sensitive with the Leclanché battery. We might naturally expect that a change in the current employed would cause a change in the *resistance* of a cell, but it is not clear how or why it should affect the *sensitiveness of selenium to light.*

"If one kind of battery current destroys its sensitiveness, may we not suppose that another kind might increase its sensitiveness? Although the Leclanché has operated well, some other may operate still better, and by its special fitness for use on selenium cells may intensify their actions, and so bring to light other properties yet unthought of. Is not here a promising field for experiment, in testing the various forms of battery already known, or even devising some new form especially adapted to the needs and peculiarities of selenium cells?"

One year ago I made the foregoing suggestion in a paper on *A New Form of Selenium Cell*, presented before this Association at Minneapolis. I am now at liberty to state that my photo-electric battery, presently to be described, marks an advance in the direction indicated. The current from this battery increases the sensitiveness of the cells to light, and also to reversal of current. One cell whose highest ratio in light was about 83 to 1, with the Leclanché battery, when measured with my battery gave a ratio of 120 to 1. It seems to make the resistance of the cell both higher in dark and lower in sunlight than with the Leclanché battery. But the field is yet open to others, for the discovery of a battery which may be still better for use with selenium cells.

3. *The two surfaces of the selenium act differently towards currents* sent into them from the contiguous conductors. One surface offers a higher resistance to the current than the other. The former I utilize as the anode surface, as I have found that the cell is more sensitive to light when the current enters at that surface, which is ordinarily the one covered by the gold or other transparent conductor. Some cells have this property but feebly developed; but in one instance the resistance offered to the current by the anode surface was 256 times as high as that offered by the cathode surface to the same current. In the majority of cases, however, the ratio does not exceed ten times. Table B gives some recent results.

TABLE B.

SENSITIVENESS TO REVERSAL OF DIRECTION OF CURRENT.

| No. of cell. | Battery. | Resistance, "gold anode." | Resistance, "gold cathode." | Ratio. |
|---|---|---|---|---|
| ¾ inch square, No. 4 | 5 elements | 20,000 ohms | 1,000 ohms | 20 to 1 |
| ¾ " " " 3 | *Se.* cell. | 6,500 | 400 " | 16.2 " " |
| Full size, No. 13 | 1 element | 9,000 " | 800 " | 11.2 " " |
| " " " 14 | 5 " | 2,440 " | 130 " | 18 " " |
| " " " 15 | 5 " | 4,640 " | 210 " | 22 " " |
| " " " 27 | 5 " | 6,900 " | 440 " | 16 " " |
| " " " 126 | 1 " | 5,000 " | 330 " | 15 " " |

The direction of the current is always indicated by stating the position of the gold electrode,— by the terms "gold anode" and "gold cathode." The above measurements were made in dark.

4. *Sensitiveness to change of battery power.* My cells are extremely sensitive to any change in the strength or character of the current flowing through them, which is shown by a corresponding change in the resistance of the cell. I can, therefore, vary the resistance of one of my cells in many ways, and the following may be specified,—

(*a*) By changing the potential or electromotive force of the current through the cell.

(*b*) By changing the "quantity" of the battery or current.

(*c*) By putting more or less resistance in the circuit.

(*d*) By dividing the current, by one or more branch circuits or shunts around the cell.

(*e*) By varying the resistance in any or all of said circuits.

A cell whose resistance becomes greater as the battery power becomes greater, and *vice versa*, I call an "L B cell" signifying *Like the Battery power*. A "U B cell" is one whose resistance becomes greater as the battery power (or strength of current) becomes less, and *vice versa*, being *Unlike the Battery power* or current strength.

These changes of resistance are not due to heating of the conductor or the selenium, and the following instance will illustrate this. I have one cell in which the selenium had about one-fourth inch square of surface melted on a brass block one inch thick.

This cell measured, with 25 elements of Leclanché, 40,000 ohms. On changing the battery to 5 elements the resistance fell instantly to 30 ohms, and there remained. On again using the current from 25 elements, the resistance instantly returned to 40,000 ohms. Had these results been due in any degree to heating, the resistance would have changed gradually as the heat became communicated to the brass,— whereas no such change occurred, the resistances being absolutely steady. Moreover, even the fusion of the selenium would not produce any such change.

The "U B" property does not ordinarily change the resistance of the cell to exceed ten times, *i. e.*, the resistance with a weak current will not be over ten times as high as with a strong one. But I have developed the "L B" property to a far higher degree. Table C gives some recent results obtained with L B cells, including one whose resistance, with 25 elements Leclanché, was 11,381 times as high as with 8 elements, and which, after standing steadily at 123 ohms (and then at 325 ohms with 1 element), on receiving the current from 25 elements again returned to its previous figure of 1,400,000 ohms.

TABLE C.

SENSITIVENESS TO CHANGE OF BATTERY POWER.

| No. of cell. | Resistance with 25 elements. | Resistance with 5 elements. | Ratio of change. |
|---|---|---|---|
| ¾ inch square, No 1 | 40,000 ohms | 30 ohms | 1,333 to 1 |
| ¾ " " " 2 | 13,000 " | 40 " | 325 " " |
| ¼ " " " 1 | 1,400,000 " | 123[a] " | 11,381 " " |
| ¼ " " " 2 | 500,000 " | 62 " | 8,064 " " |
| ¼ " " " 5 | 3,500 " | 21 " | 167 " " |
| Full size, No. 81 | 68,000 " | 121 " | 561 " " |
| " " " 82 | 9,000 " | 64 " | 140 " " |
| " " " 83 | 17,300 " | 74 " | 233 " " |
| " " " 119 | 35,600 " | 19 " | 1,894 " " |

The results in the table were obtained by changing the strength of current by throwing in more or less of the battery. Like results can be obtained by varying the current through the cell by any of the other methods before specified. The above measurements were in dark.

[a] This measurement was obtained with 8 elements.

5. *Dual state of selenium.* My cells, when first made, seem to have two states or conditions. In one, their resistance is very low, in the other it is high. When in the low state they are usually not very sensitive, in any respect. I therefore raise the resistance, by sending an intermittent or an alternating current through the cells, and in their new condition they at once become extremely sensitive to light, currents, and other influences. In some cases they drop to the low state again, and require to be again brought up, until, after a number of such treatments, they remain in the sensitive state. Occasionally a cell will persist in remaining in the insensitive state. The before-mentioned treatment raises it up for a moment, but, before the bridge can be balanced and the resistance measured, it again drops into the low or insensitive state. Some cells have been thus stimulated into the high or sensitive state repeatedly, and every means used to make them stay there, but without avail; and they have had to be laid aside as intractable.

In the earlier stages of my investigations, before the discovery of this dual state and the method of changing a cell from the insensitive to the sensitive condition, hundreds of cells were made, finished, and tested, only to be then ruthlessly destroyed and melted over, under the impression that they were worthless. Now I consider nothing worthless, but expect sooner or later to make every cell useful for one purpose or another.

The most singular part of this phenomenon is the wide difference in the resistance of the cells in the two states. In the low state, it may be a few ohms, or even a few hundredths of an ohm. In the high state, it is the normal working resistance of the cell, usually between 5,000 and 200,000 ohms, but is often up among the millions. The spectacle of a little selenium being stimulated, by a few interruptions of the current through it, into changing its resistance from a fraction of an ohm up to a million or several millions of ohms, and repeatedly and instantly changing back and forth, up and down, through such a wide range,—we might almost say, changing from zero to infinity, and the reverse, instantly,—is one which suggests some very far-reaching inquiries to the electrician and the physicist. What is the nature of electrical conductivity or resistance, and how is it so greatly and so suddenly changed?

6. *Radio-electric current generators.* My cells can be so treated

that they will generate a current by simple exposure to light or heat. The light, for instance, passes through the gold and acts upon its junction with the selenium, developing an electromotive force which results in a current proceeding from the metal back, through the external circuit, to the gold in front, thus forming a photo-electric dry pile or battery. It should preferably be protected from overheating, by an alum water cell or other well known means.

The current thus produced is radiant energy converted into electrical energy directly and without chemical action, and flowing in the same direction as the original radiant energy, which thus continues its course, but through a new conducting medium suited to its present form. This current is continuous, constant, and of considerable electromotive force. A number of cells can be arranged in multiple arc or in series, like any other battery. The current appears instantly when the light is thrown upon the cell, and ceases instantly when the light is shut off. If the light is varied properly, by any suitable means, a telephonic or other corresponding current is produced, which can be utilized by any suitable apparatus, thus requiring no battery but the selenium cell itself. The strength of the current varies with the amount of light on the cell, and with the extent of the surface which is lighted.

I produce current not only by exposure to sunlight, but also to dim diffused daylight, and even to lamplight. I have used this current for actual working purposes,— among others, for measuring the resistance of other selenium cells, with the usual Wheatstone's bridge arrangement, and for telephonic and similar purposes. Its use for photometric purposes and in current-regulators, will be mentioned farther on. It is undoubtedly available for all uses for which other battery currents are employed, and I regard it as the most constant, convenient, lasting, readily used and easily managed pile or battery of which I have any knowledge. On the commercial scale, it could be produced very cheaply, and its use is attended by no expense, inasmuch as no liquids or chemicals are used, the whole cell being of solid metal with a glass in front, for protection against moisture and dust. It can be transported or carried around as easily and safely as an electro-magnet, and as easily connected in a circuit for use wherever required. The current, if not wanted immediately, can either be "stored" where produced, in storage

batteries of improved construction devised by me, or transmitted over suitable conductors to a distance, and there used, or stored as usual till required.

7. *Singing and speaking cells.* When a current of electricity flowing through one of my selenium cells is rapidly interrupted, a sound is given out by the cell, and that sound is the tone having the same number of air vibrations per second as the number of interruptions in the current. The strength of the sound appears to be independent of the direction of the current through the cell. It is produced on the face of the cell, no sound being audible from the back of the cell. An alternating current also produces a sound corresponding to the number of changes of direction. Experiments also show that, if a telephonically undulating current is passed through the cell, it will give out the speech or other sound corresponding to the undulations of the current,—and, furthermore, that the cell will sing or speak in like manner, without the use of a current, if a suitably varied light is thrown upon it while in closed circuit.

My experiments having been devoted especially to those branches of the subject which promised to be more immediately practically valuable, I have not pursued this inquiry very far, and offer it for your consideration as being not only interesting, but possibly worthy of full investigation.

*General Observations on the Properties of Cells.*

From the number of different properties possessed by my cells, it might be anticipated that the different combinations of those properties would result in cells having every variety of action. This is found to be the case. As a general rule, the cells are noteworthy in one respect only. Thus, if a cell is extremely sensitive to light, it may not be specially remarkable in other respects. As a matter of fact, however, the cells most sensitive to light are also "U B cells."

The property of sensitiveness to light is independent of the power to generate current by exposure to light,—the best current-generating cells being only very moderately sensitive to light, and some of the most sensitive cells generate scarcely any current at all. Current-generating cells are, almost without exception, "U B cells;" and the best current-generating cells are strongly polarized, showing a considerable change of resistance by reversing the direction of a current through them; and they are also

strong "anode cells," *i. e.*, the surface next to the gold offers a higher resistance to a battery current than the other surface of the selenium does. The power to generate a current is temporarily weakened by sending a battery current through the cell while exposed to light, in either direction. The current generated by exposure to light is also weakened by warming the cell, unless the cell is arranged for producing current by exposure to heat.

The properties of sensitiveness to light and to change of battery power are independent of each other, as I have cells which are sensitive to change of current but absolutely insensitive to light,—their resistance remaining exactly the same whether the cells are in darkness or in sunlight. I also have cells which are sensitive to light, but are unaffected by change of battery power, or by reversing the direction of the current through them.

The sensitiveness to change of battery power is also independent of the sensitiveness to reversal of direction of the current. Among the best "L B cells," some are "anode cells" and others are "cathode cells," while still others are absolutely insensitive to reversal of current, or to the action of light.

*Constancy of the resistance.* A noticeable point in my cells is the remarkable constancy of the resistance in sunlight. Allowing for differences in the temperature, the currents, and the light, at different times, the resistance of a cell in sunlight will remain practically constant during months of use and experiments, although during that time the treatments received may have varied the resistance in dark hundreds of thousands of ohms,—sometimes carrying it up, and at others carrying it down again, perhaps scores of times, until it is "matured" or reaches the condition in which its resistance becomes constant.

As has already been stated, the sensitiveness of a cell to light is increased by proper usage. This increased sensitiveness is shown, not by a lowered resistance in light, but by an increased resistance in dark. This change in the cells goes on, more or less rapidly, according as it is retarded or favored by the treatment it receives, until a maximum is reached, after which the resistance remains practically constant in both light and dark, and the cell is then "matured" or finished. The resistance in dark may now be 50 or even 100 times as high as when the cell was first made, yet, whenever exposed to sunlight it promptly shows the same resistance that it did in the beginning. The various treatments, and even

accidents, through which it has passed in the meantime, seem not to have stirred its molecular arrangement under the action of light, but to have expended their forces in modifying the positions which the molecules must normally assume in darkness.

*Practical applications.* There are many peculiarities of action occasionally found, and the causes of such actions are not always discernible. In practice, I have been accustomed to find the peculiarities and weaknesses of each cell by trial, developing its strongest properties and avoiding its weaknesses, until, when the cell is finished, it has a definite and known character, and is fitted for certain uses and a certain line of treatment, which should not be departed from, as it will be at the risk of temporarily disabling it. In consequence of the time and labor expended in making cells, in the small way, testing, repairing damages done during experiments, etc., the cost of the cells now is unavoidably rather high. But if made in a commercial way all this would be reduced to a system, and the cost would be small. I may say here that I do not make cells for sale.

The applications or uses for these cells are almost innumerable, embracing every branch of electrical science, especially telegraphy, telephony and electric lighting, but I refrain from naming them. I may be permitted, however, to lay before you two applications, because they are of such general scientific interest. The first is my

*Photometer.* The light to be measured is caused to shine upon a photo-electric current-generating cell, and the current thus produced flows through a galvanometric coil in circuit, whose index indicates upon its scale the intensity of the light. The scale may be calibrated by means of standard candles, and the deflections of the index will then give absolute readings showing the candle-power of the light being tested. Or, the current produced by that light and that produced by the standard candle may be compared, according to any of the known ways of arranging and comparing different lights,—the cell being lastly exposed alternately to the two lights, to see if the index gives exactly the same deflection with each light.

This arrangement leaves untouched the old difficulty in photometry, that arising from the different *colors* of different lights. I propose to obviate that difficulty in the following manner. As is well known, gold transmits the green rays, silver the blue rays, and so on; therefore, a cell faced with gold will be acted

upon by the green rays, one faced with silver by the blue rays, etc. Now if we construct three cells (or any other number), so faced that the three, collectively, will be acted upon by all the colors, and arrange them around the light to be tested, at equal distances therefrom, each cell will produce a current corresponding to the colored rays suited to it, and all together will produce a current corresponding to all the rays emitted by the light, no matter what the proportions of the different colors may be. The three currents may act upon the same index, but each should have its own coil, not only for the sake of being able to join or to isolate their influences upon the index, but also to avoid the resistances of the other cells. If a solid transparent conductor of electricity could be found which could be thick enough for practical use and yet would transmit all the rays perfectly, *i. e.*, transmit white light unchanged, that would be still better. I have not yet found a satisfactory conductor of that kind, but I think the plan stated will answer the same purpose. This portion of my system I have not practically tested, but it appears to me to give good promise of removing the color stumbling-block which has so long defied all efforts to remove it, and I therefore offer it for your consideration.

*Photo-electric regulator.* My regulator consists of a current-generating cell arranged in front of a light, say, an electric lamp whose light represents the varying strength of the current which supports it. The current produced in the cell by this light flows through an electro-magnetic apparatus by means of which mechanical movement is produced, and this motion is utilized for changing resistances, actuating a valve, rotating brushes, moving switches, levers, or other devices. This has been constructed on a small scale and operates well, and I think it is destined to be largely used, as a most sensitive, simple and perfect regulator for currents, lights, dynamos, motors, etc., etc., whether large or small.

*In conclusion*, I would say that the investigation of the physical properties of selenium still offers a rare opportunity for making very important discoveries. But candor compels me to add that whoever undertakes the work will find it neither an easy nor a short one. My own experience would enable me to describe to you scores of curious experiments and still more curious and suggestive results, but lack of time prevents my giving more than this very incomplete outline of my discoveries.

## RELATION BETWEEN THE ELECTROMOTIVE FORCE OF A DANIELL CELL AND THE STRENGTH OF THE ZINC SULPHATE SOLUTION.

By Prof. H. S. CARHART, N. W. University, Evanston, Ill.

[ABSTRACT.[1]]

THIS investigation was carried out in the physical laboratory of the university in Berlin. The electromotive force was measured by the compensation method of Poggendorff. The two poles of the battery *A* to be measured are connected with two points on a second circuit containing a battery *B* of higher electromotive force than *A*. The resistance between the points is then varied till no current flows through the circuit of battery *A*. The difference of potential between the two points common to the two circuits is then equal to the electromotive force to be measured. By Ohm's law the product of the resistance between the two points and the current flowing through the main circuit equals the electromotive force of the battery *A*.

The current was measured by a silver voltameter with pure nitrate of silver. The resistance employed was in Siemens' units. The deposition of silver in a silver cup was continued ten minutes with a current of slightly over one-tenth of an ampère. The cup was then washed with great care, dried in a hot-air chamber, and weighed after cooling, fractions of milligrams being obtained by taking the swing of the pointer.

The cell to be measured consisted of a *U* tube, the bend being much smaller than the two branches, the form being that employed by Kohlrausch in measuring the resistance of electrolytes. The lower portion of the tube was first filled with a saturated solution of zinc sulphate; copper sulphate was then added to one branch and a percentage solution of zinc sulphate to the other, the surface of separation between the two adjacent solutions being sharp in each case. No perceptible diffusion of the solutions took place during the time required for the measurement of the current.

The following condensed table exhibits the results:

[1] Printed in full in Am. Jour. Sci., Nov., 1884.

| | | | Silver deposited in one minute. | Product of resistance and silver. | Corrected for temp'ure of rheostat. | Mean value of product. | E. M. F. in volts. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 1 | 0 | 11 | 6.727 mgs. | 73.997 | 73.997 | 73.997 | |
| 1 | 18.8 | 11 | 7.277 " | 80.057 | 80.000 | 80.000 | 1.125 |
| 2 | 18 | 11 | 7.339 " | 80.729 | 80.664 | 80.584 | 1.133 |
| | 19.5 | 12 | 6.710 " | 80.520 | 80.504 | | |
| 3 | 17.8 | 11 | 7.493 " | 81.653 | 81.581 | 81.216 | 1.142 |
| | 17.4 | 11 | 7.356 " | 80.938 | 80.851 | | |
| 4.5 | 17.3 | 11 | 7.289 " | 79.639 | 79.546 | 79.620 | 1.120 |
| | 18.3 | 11 | 7.250 " | 79.750 | 79.694 | | |
| 10 | 17 | 11 | 7.294 " | 79.464 | 79.369 | 79.490 | 1.118 |
| | 19.3 | 11 | 7.239 " | 79.634 | 79.612 | | |
| 15 | 20 | 11 | 7.219 " | 79.409 | 79.409 | 79.305 | 1.115 |
| | 18.3 | 11 | 7.205 " | 79.255 | 79.201 | | |
| 20 | 17.3 | 11 | 7.170 " | 78.870 | 79.785 | 79.008 | 1.111 |
| | 17.5 | 11 | 7.210 " | 79.310 | 78.231 | | |
| 30 | 16.3 | 11 | 7.199 " | 79.189 | 79.072 | 78.997 | 1.111 |
| | 16.6 | 11 | 7.184 " | 79.030 | 78.923 | | |

Mean, 1.122

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[illegible] OF PHOTOGRAPHIC DRY PLATES. By WM. H. PICK[illegible], Mass. Inst. of Technology, Boston, Mass.

[ABSTRACT.]

[illegible] object of this research was to determine the sensitiveness [illegible] kinds of dry-plates on an absolute scale, and to [illegible] terms of the sensitiveness of pure silver chloride. The [illegible] exposed in a box one meter in length having an [illegible] cm. in diameter at one end. It is exposed under [illegible] of tissue paper to the light from the blue sky in [illegible] a definite time, say eight minutes. The plates to [illegible] cut up in narrow strips, and exposed under the [illegible] aperture (.05 cm. in diameter) for a shorter

time, say 30 seconds. The last degrees of the scale as printed on the chloride, and photographed on the plates, are then noted and the relative amount of light received in the two cases compared, thus giving the absolute sensitiveness of the plates in terms of the sensitiveness of the chloride. The observations were repeated using gas-light as a source of illumination, and it was found that those plates most sensitive to daylight were in several cases the least so to gaslight.

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PHOTOGRAPHY OF THE INFRA-RED REGION OF THE SPECTRUM. By WM. H. PICKERING, Mass. Inst. of Technology, Boston, Mass.

[ABSTRACT.]

IN the investigation described below, ordinary gelatine dry plates were employed. It was soon found, however, that some kinds were much more suitable for this purpose than others. Walker Reid and Inglis, and Allen and Rowell plates, being those which gave the best results. With an ordinary spectroscope, with one flint glass prism, there is no difficulty, by concentrating the light, in photographing as far below A, as A is below D on the prismatic spectrum, or to w. l. 11300. In order to do this one need only place two pieces of red glass before the slit and give a sufficient exposure. It is well to paint the back of the plate black, to avoid the halo produced by the brighter portions of the spectrum. By using a four inch prism, and camera lens, the latter of about twelve inches focus, one may reach a wave length of 13800 in about ten minutes. By using a wide slit of about 15′ angular aperture the A line may be photographed in about a third of a second, and a few seconds more is sufficient to cause the spectrum in the neighborhood of the C line to reverse and become nearly transparent.

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THUNDERSTORMS AND THEIR RELATIONS TO "LOW." By Prof. HENRY A. HAZEN, O. C. S. O., Washington, D. C.

[ABSTRACT.[1]]

PROF. TAIT'S views as to the origin of atmospheric electricity. The work of Palmieri in Italy and of Bezold in Bavaria; especially

[1] Presented by permission of the Chief Signal Officer of the Army.

in determining the general distribution of thunderstorms on any day and the laws governing their origin, development and progress.

The great advantage this country offers for such study. The special investigations begun in January of this year and continued to the present time. Results.

A study of the storms of May 17–20 leads to the following conclusions:

1. Hail falls occurred, with relatively low pressure at a storm centre, in the region to the southeast of "LOW" and at distances of about 250 miles.

2. Thunderstorms were also mostly in the same region but at distances, on the average, of 450 miles. In cases where these occurred to the west and northwest of "LOW," they were sporadic and of little intensity.

3. In this region the winds were gentle and southerly.

4. In many instances there was a furious gust of wind from the west immediately preceding the storm, an increase of eight and ten times the previous velocity in a few minutes.

5. In a few cases where the barometer was frequently read it was found to indicate a rather sudden increase in pressure as the storm came up.

6. The intensity was greatly diminished at nightfall and again increased the day following.

7. The velocity at which the storms travelled from west to east, spreading somewhat in a fan shape, was, on May 19, from 10 A. M. to 3 P. M., 37 miles per hour; from 3 P. M. to 10 P. M., 38 miles per hour, while the velocity of "LOW" was 23 and 10 miles per hour, respectively.

This seems to show that the relation, if there be one, is with the general disturbance rather than with its centre and that the forces which determine the formation and progress of thunderstorms are in a manner independent of those acting in the "LOW" itself.

Is this greater velocity of thunderstorms than of "LOW," due to their distance from the centre and a consequent greater circumferential motion?

NOTES ON ACOUSTICS. By Prof. CHAS. R. CROSS, Mass. Institute of Technology, Boston, Mass.

[ABSTRACT.]

I. *Quality of sound as related to Change of Phase.* When an induction coil is used in telephony there is of course a difference of phase of a quarter of a wave-length between the electrical undulation in the primary and that in the secondary circuit owing to the action of the induction coil. Hence, if any complex musical sound is transmitted by such an apparatus there is a great change in the phase-relations among the partial-tones of the note. If the quality were to be noticeably altered by such a change there should be a perceptible difference in quality between the sound heard in two receiving telephones, one in the primary and the other in the secondary circuit of an induction coil connected up in the ordinary manner with a microphone or other transmitter. No differences of this kind have been perceived either with the tones of such musical instruments I have transmitted, or with the voice. By suitably adjusting the resistance of the two telephone receivers even the loudness of the sounds heard in the two circuits can be made identical. There is no perceptible change of phase from self-induction in the simple circuit described.

II. *Remarks on a Point in Helmholtz's Theory of Consonance and Dissonance.* Helmholtz considers beats to be due to an interference of vibrations in the vibrating parts of the inner ear, and assumes that no two sounds can produce beats unless the interval between them is so small that they both affect the same vibrating part of the inner ear. In addition to Koenig's experimental disproof of the supposition that notes cease to beat when their interval is considerable, the view of Helmholtz as to the physiological action in the ear is in opposition to certain undoubted facts of audition. Beats may occur either between a sound and the after sensation of a previous sound, and, still more, between two sounds acting only upon opposite ears. The latter fact I have confirmed by observing the beats between mistuned unisons and other mistuned intervals given by two tuning-forks; one acting directly upon one ear, and the other transmitted by telephone to the other ear. The beating with the after sensation shows that unless the after-sensation itself is due to persistence in vibration of the vibrating parts (which is certainly not the fact) the discussion of Helmholtz is in-

complete. This view is still further confirmed by the production of beats from the excitation of separate ears. There must be a deeper action than that considered by Helmholtz, a kind of interference in the sensorium itself instead of, or rather, in addition to, the interference of vibrations in the inner ear.

III. *Intensity of Sound as related to Amplitude of Vibration.* In the ordinary statement that the intensity of sound is proportioned to the square of the amplitude of vibration, a proposition that has of late been clearly recognized as applying in any case only to sounds of the same pitch, the complexity of the relation between the intensity of the vibration exciting the ear, and the resulting sensation has been universally lost sight of. Probably, though not certainly, the Psychophysic Law of Fechner applies to intensity-variations, and the sensation certainly does not increase as rapidly as the exciting cause. Hence, in strictness, we cannot assume the ordinary statement to be accurately true except in applying it to objective sound. It is a mechanical rather than an aural measure of the intensity, that we assume.

Also in the diminution of intensity with increase of distance, the sensation must diminish less rapidly than the law of inverse squares would lead us to suppose.

IV. *On a Musical Application of the Principle of Fatigue.* In the so-called "Voix celeste" stop in cabinet organs a tremolo is produced by calling into play two sets of reeds just out of unison with each other, which make slow beats with each other and with the notes produced on other stops in use at the same time. Besides this, there is a remarkable strengthening of the whole body of tone from the instrument. This seems to arise from the increased average intensity of the sensation due to the alternate increase and decrease of sound, which, however, with the slow beats used, is not so great as to become harsh and painful.

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ON A PROPOSED METHOD FOR ASCERTAINING THE LEAST NUMBER OF VIBRATIONS NECESSARY TO DETERMINE PITCH. By Prof. CHAS. R. CROSS, Mass. Institute of Technology, Boston, Mass.

[ABSTRACT.]

THE methods hitherto used for this purpose are all of them defective for the reason that the vibrations produced are complex in their nature instead of being pendular. In the method proposed

pendular vibrations are employed. Two magnetic-telephones are connected up with each other in the usual manner, and a circuit-making wheel with a single radial metallic strip is interposed, so that by the rotation of the wheel the circuit shall remain closed for a short interval, which can be determined by the rapidity of rotation. If the sound of a tuning-fork giving pendular vibrations is transmitted through the circuit a greater or less number of these vibrations, or even a fractional part of a single one, can be caused to act upon the ear. Suitable precautions are taken to avoid the production of extraneous sounds in the circuit itself. A properly adjusted microphone transmitter with an induction coil may be substituted for the magneto-transmitter, the circuit-making wheel being placed in the secondary circuit.

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UPON A GENERATOR IN USE AT CORNELL UNIVERSITY FOR PRODUCING OXYGEN AND HYDROGEN GAS BY MEANS OF THE DYNAMO MACHINE. By Prof. WM. A. ANTHONY, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE generator which forms the subject of this paper has now been in use for more than three years at the Cornell University with such good results that it is deemed worth while to give some account of it. The generator consists of twelve cells, each cell being essentially a U tube of white earthen ware with suitable openings for introducing the electrodes and for replenishing the fluid. The electrodes are of platinum foil $2\frac{1}{4} \times 5$ inches, attached to the ends of lead tubes which serve at the same time for conveying the current and delivering the gas. The openings are stopped by paraffined corks, and the tubes from the several cells are connected to the general delivery tubes (of lead) in the same way. The twelve cells are connected electrically in series.

In an experiment to determine the maximum amount of gas to be obtained by the power at command (about 5 H. P.) the result was as follows:

Amount of both gases evolved in three hours 544.8 litres, or .00226 grms. per cell per second. This would correspond to 24.49

ampères, while a large tangent galvanometer indicated 25.22. The discrepancy is not surprising as the amount of gas was determined by measuring the rise of the gasholders, four feet in diameter, in which the gas was collected, a measurement not calculated to give very great accuracy.

The E. M. F. employed was 123.08 volts, and the energy employed 3104.08 watts.

The useful energy represented by the gases generated was 429 watts, and the efficiency 13.8 per cent. This is a small efficiency, but it is evident that it might be much increased for the same apparatus by using less energy per second, and producing gas less rapidly. In another experiment in which only three-fourths as much gas per hour was obtained, the usual rate of running the apparatus, the efficiency was twenty-four per cent. The resistance of the cells might be much diminished and their efficiency increased by using in place of the U tube, a vessel with a porous partition extending to near the bottom. The part of the partition above the liquid could be glazed; but even if it were not, there would be no appreciable mixture of the gases through it, since it would be always wet.

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## DETERMINATION OF THE COEFFICIENT OF EXPANSION OF THE SPECULUM METAL USED FOR ROWLAND'S GRATINGS.

By Prof. WM. A. ROGERS, Harvard Observatory, Cambridge, Mass.

[ABSTRACT.]

THE coëfficient of the speculum metal cast by Mr. Brashear with the components given by Professor Rowland, and determined in this paper, was derived from a half yard and half meter bar prepared for Professor Wead of Michigan University.

The comparisons were made as follows;

(*a*) With the steel screw of dividing engine.
(*b*)* With bronze meter $R_2$
(*c*)* With steel meter $R_3$

* See Proceedings American Academy Vol. XVIII, p. 383.

The following results were obtained.

| | From steel screw. | From $R_1$ | From $R_2$. |
|---|---|---|---|
| Absolute coëfficient | 10.65$\mu$ | 17.17$\mu$ | 10.27$\mu$ |
| Relative coëfficient for speculum metal | +7.36 | +0.82 | +7.70 |
| Absolute coëfficient for speculum metal | 18.02 | 17.99 | 17.97 |

The absolute coëfficient of this particular piece of metal is therefore 17.99$\mu$ for each degree Centigrade.

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ADDITIONAL OBSERVATIONS CONFIRMING THE RELATION: METRE DES ARCHIVES = IMPERIAL YARD + 3.37027 INCHES. By Prof. WILLIAM A. ROGERS, Harvard Observatory, Cambridge, Mass.

[ABSTRACT.]

SINCE the determination of the relation between the yard and the meter, communicated to the Association at the Minneapolis Meeting, additional data bearing upon the subject have been obtained. It will be remembered that the relation was derived from a yard and meter laid off upon a bar of bronze having the same form and dimensions in cross section as the Imperial yard.

Representing the yard by the line $AB$, and the meter by the line $AC$, the operation consisted: —

(*a*) In the determination of the length of $AC$ in terms of the Metre des Archives, $A_0$ through a comparison with a meter upon copper traced and standardined by Tresca and with a meter upon brass belonging to the Stevens Institute and compared with Type I of the International Bureau of Weights and Measures at Breteuil by Dr. Benoit.

(*b*) In the determination of the length of $AB$ in terms of the Imperial Yard through comparisons with "Bronze 11" belonging to the United States Coast Survey and with a yard upon brass belonging to the Stevens Institute which has been compared directly with the Imperial Yard by Mr. Chaney, Warden of the Imperial Standards.

[illegible] in terms of either $AB$ or $AC$.

[illegible] additional data have been

[illegible] Studies in Metrology, Proceedings of the [illegible], Vol. XVIII, p. 382, the following relations

[illegible] of the bronze metre $R_2$ and the steel meter [illegible] metre T, designating the metre des Archives

$$R_1^{0} - A_0 = -3.2\mu.$$
$$R_2^{0} - A_0 = +1.5\mu.$$

[illegible] of the metres $R_1$ and $R_2$ with the Stevens [illegible] designated C S,

$$R_1^{0} - A_0 = -2.5\mu.$$
$$R_2^{0} - A_0 = +1.1\mu.$$

[illegible] coefficient of expansion for the bars T, C S, [illegible] given on page 380, viz.:

[illegible] coefficient for 1°C. = 16.18$\mu$.
[illegible] " " " = 17.60$\mu$.
[illegible] " " " = 10.11$\mu$.
[illegible] " " " = 17.17$\mu$.

[illegible] C S was derived from the provisional [illegible] Pernet, viz.:

[illegible] + 310.0$\mu$ = $A_0$.

[illegible] of this metal determined at [illegible] calculated at the time of the publication [illegible] necessary to use the value given [illegible] to 16.67° C. or to 62.0°

[illegible] Dr. Pernet not only the exact [illegible] and Type I of the Bureau, but also [illegible] for this bar. The following [illegible]:

[illegible] + 310.7 = $A_0$
[illegible] = [illegible]$\mu$ for each degree C.

[illegible] originally employed, we [illegible] between $R_1$ and $A_0$:

From the Tresca meter, $R_2^{a^2} - A_0 = +1.5\mu$.

From meter C S, [Rogers,] $R_2^{a^2} - A_0 = +1.1\mu$.

From meter C S, [Benoit,] $R_2^{a^2} - A_0 = +2.3\mu$.

(*b*) In the reduction of the comparisons of the yard $R_2^{a^2}$ with "Bronze 11," the relation

"Bronze 11" + .000088 inch = Imperial Yard,

as determined by Hilgard and Chaney, was employed. From the Report of the Standard Department for 1883, it appears that Pierce found the relation

"Bronze 11" + .0000022 inch = Imperial Yard.

Substituting the latter relation for the former, I find:

From mean of observations by Mr. Edwin Smith and myself,

$$R_2^{a^2} - 0.2\mu = \text{Imperial Yard.}$$

From the relation between C S and the Imperial Yard given by Mr. Chaney,

$$R_2^{a^2} - 0.9\mu = \text{Imperial Yard.}$$

(*c*) For the determination of the distance *BC* a combined decimeter and four-inch space have been laid off upon speculum metal. The fourth inch is subdivided to tenths of inches and the fourth tenth is subdivided to thousandths of an inch. The decimeter is subdivided to centimeters. The eighth centimeter is subdivided to tenths and the fifth tenth is subdivided to hundredths of millimeters.

The preliminary measures by means of this auxiliary scale give a result slightly less than the value found in 1883. The observations will be repeated several times before the final result will be announced.

So far, the effect of these additional data has been to diminish slightly the value of 3.37027 inches, but the final result cannot fall below the relation first announced, viz., 3.37015 inches.

A METHOD FOR THE PRACTICAL EXAMINATION OF RAILWAY EMPLOYÉS AS TO COLOR BLINDNESS, ACUTENESS OF VISION AND HEARING, WITH THE RESULTS OBTAINED BY IT ON THE PENNSYLVANIA RAILROAD. By WILLIAM THOMSON, M.D., Prof. of Ophthalmology, Jefferson Medical College, Philadelphia, Pa.

SHORTLY after the demonstrations of Prof. Holmgren in Sweden of the dangers in transportation to persons and property on land and sea from color-blindness, the writer called the attention of the officers of the Pennsylvania R.R. to the subject; and at the request of the President Mr. Thos. A. Scott, and the Vice President Mr. Frank Thomson, he undertook to solve the problem of eliminating these dangerous men from their services. To his first statement that there were probably four per cent of men incapable of distinguishing unerringly between red and green flags by day, or lights by night, it was responded that their signals alone would detect such men, and force them from their places, since, as we all know, the most imperative orders in railway administration are transmitted through the visual organs, in the White of "Safety" the Green of "Caution", and the Red of "Danger", and it was considered by the officers of the road impossible for men color blind to pass the thousands of signals in daily use on their thousands of miles of road without detection. A very slight search dispelled this idea, and a demonstration of the defect before the Society of Transportation Officers of the Pennsylvania Railroad aroused the members of it to the dangers to be feared, and led to the appointment of a special committee to aid the writer in completing a system which would have practicable value, with the General Manager Mr. Pugh, as its Chairman, to whose keen interest much of its success now is due.

The magnitude of the task then began to appear, when the forty or fifty thousand employés of five thousand miles of track, with their ten or twelve thousand men actually dependent upon signals of color for their guidance, of whom four per cent might be color blind, and ten per cent so defective in visual power for form, and hearing, as to render them dangerous, arose before the imagination. To have adopted the method of Holmgren, by which an accomplished ophthalmic surgeon would conduct the examination of each man, would have demanded years of his entire time, would have been so tardy as to allow large additions to the

force before it could be accomplished, and was soon rejected as impracticable; neither was it thought possible to train a sufficient number of the company's surgeons to perform this special task with fairness to the men, and safety to the company.

To secure the coöperation of the employés, the officers needed a system that could be applied locally on each division quietly and confidentially, and at the convenience of the men, without compelling them to lose much time. Any undue publicity or inexorable law that would compel the summary discharge of from ten to fifteen per cent of their trained operatives would have disorganized the service, and destroyed the discipline of the company; and for their own protection and as a duty to the public the officers were willing to put on trial any practicable scheme, without the pressure of any over-anxious public opinion or hostile legislation.

These, and other considerations of weight, led the writer to the invention of an instrument (Fig. 1) for the examination of the color sense which could be efficiently used by any intelligent instructed official, and a record of it permanently kept for the information of the officers, and as a guide for the action of any surgical expert

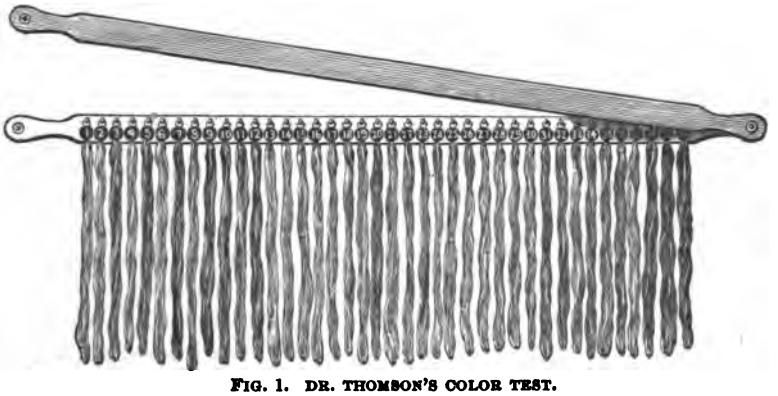

FIG. 1. DR. THOMSON'S COLOR TEST.

whom the road might appoint to superintend the entire system. This consists of forty skeins of wool, each one attached to a button, having the figures from one to forty inscribed on them, suspended from two flat sticks, so arranged that the numbers are concealed. Holmgren's method of matching colors is adhered to, and the test colors to be matched are green, rose, and red; the skeins from one to twenty being used for green, those from twenty-

one to thirty for rose and from thirty-one to forty for red; upon the *odd* numbers are suspended green, rose, and red skeins, upon the *even* ones those "confusion colors" which the experience of the writer had taught him would be the most likely to be selected by the color blind. In its use a green skein is placed before the person at a few feet distant, and he is directed to select those of that color from the stick, and to turn them away, or throw them over; then the rose, then the red: and as this is done for each test skein, the numbers upon the buttons are inspected and recorded upon a blank. So simple is this system, that the division superintendent, who is responsible for the examination, may forget all its details if he but remember that upon the blanks submitted to him for his action must appear only odd numbers, and that if the even ones are mingled the case is one of color blindness.

For the acuteness of vision the best and most simple method is to employ letters of known size at given distances; and as we might meet with men who could avail themselves of opportunities to learn by heart, those of "Snellen," ordinarily used, the writer had a rotary disk constructed on the same principle whereby but a few letters were exposed, but many more could at will be brought into view when desired.

For the hearing, a watch and the voice in conversation were used.

These instruments, together with the rules and regulations submitted to you, won the approval of the committee of railroad officers, were put into practical use in two thousand preliminary examinations, were adopted by the highest officers, accepted by the Board of Directors and ordered to be put in force upon the entire road under the supervision of the writer as their surgical expert. His duties were to assure himself of the accuracy of all instruments, to give instructions to the examiners of the different divisions in their use, to give his opinion upon any doubtful cases, their blanks being placed before him, and to examine personally any men sent for the purpose, and to render fit for service by medical or surgical treatment, or by proper correcting glasses, any capable of such relief.

From an inspection of the blanks and a knowledge of the men, the division superintendent could deal with most of the cases by suspending or transferring them to other duties. The blanks of the color-blind and those much below the standard of vision were

transmitted to the surgical expert and, upon his advice, the men could be sent to his office, where the color-blind were re-examined by the "stick" by Holmgren's method, by that of "Stilling" advised by the last International Congress, and by Donders' instrument by which the lights of the lamps and signals at night are so perfectly imitated in color, size and intensity, and the degree of color defect measured by means of the ratios that exist between the sizes of the openings transmitting the light, and the distances at which the man may be placed; the small opening should be seen by the normal eye at five metres, being in diameter one millimeter, whilst the largest, 20 mm., when used at five metres shows $\frac{1}{20}$ of color sense when not recognized, or at one metre, shows $\frac{1}{100}$, or at $\frac{1}{3}$ of a metre or one foot, shows but $\frac{1}{300}$ of color sense, and many fail to distinguish the light at this short distance; finally by coarse tests such as colored glasses placed in front of large gas lights, and by flags near at hand. No color-blind man has lost his place without the satisfaction of a professional examination, and a full demonstration of his defect in most instances even to his own satisfaction.

Should he fail to see the red, for example, at five metres, of the large opening in Donders' instrument, or of a gas light with a red glass before it, calling it green, he would be directed to obey the green signal and approach it slowly, walking up to it until, when within one metre, perhaps he might recognize it as the danger signal, when too near to prevent an accident. Color-blindness, it must be remembered, is, in some respects, like deafness, and with the various degrees of it, there are different possibilities of disaster.

No excitement has arisen, no interference with the business of the road, no color-blind man has escaped detection, very few mistakes have been made by the examiners, not a single word has been changed in the instructions, and there is nothing to amend, except, perhaps, to make the color-stick into a smaller, more elegant and self-registering instrument.

One simple test not hitherto mentioned has been used in the first moment of my examination; by placing a piece of cobalt-blue glass in front of the man's eye, and directing him to look at a light of moderate size like a candle, at twenty feet distance, this glass will transmit both blue and crimson light, and the normal eye sees a rose-colored flame surrounded by a blue hale, whilst the color-blind sees no red, but only two shades of blue, and so describes it.

That the color-blind depend upon the relative intensity of the lights to distinguish them is shown by the fact that if over a clear light we place a medium shade of London smoke glass it will probably be called "green," whilst a deeper one will be called "red." In like manner, if a red glass, then a green one, are placed before the light, and then tints of red and green of other depths, the man will often call one red, red; and other red, green; or *vice versa*. In the display of flags that have been in use, a very bright or clean red one having been correctly called, if it is thrown carelessly near so that it can be compared by the man, and another, somewhat soiled, be shown, he may pronounce the latter green, and adhere to the opinion even when he takes it in his hand, being misled by the brightness of the cleaner one, and the relative dullness of the other.

A photograph print of the color stick will give in its tints only various ones of gray, since, as we know, colors are incapable of being rendered by this total color-blind process, whereas color-blind men have lost but the red and green, preserving perfectly the power to see yellow and blue. If now we were to paint blue that part of the print between 21 and 30, we who are not color-blind could form a clear conception of its appearance to color-blind persons and appreciate how impossible it must be for them to conceal their defects under the investigation of the color-stick. Rose, being composed of red and blue in equal quantities, appears as a tint of blue to the red blind.

It has not been the duty of the writer to investigate cases of accident which might have been caused by defects of sight, but he has been assured by officials that a solution will hereafter be found in them for those hitherto insoluble mysteries where men, otherwise credible, have so flatly contradicted themselves and the circumstances of the case. By one prominent officer he was told that, being upon a train at night, delayed by some slight accident, he himself took a red lantern and, going to a proper distance back, placed himself on the track in the way of an on-coming train, but, finding his light not observed, he was compelled to dash it into the cab to attract the engineer's attention and arrest him in his progress to a collision. Upon the examination of another engineer, his superior officer being present and convinced of his marked color-blindness, remarked that but a short time before, this man had run into the rear of a train properly protected by a red

light in the hands of a brakeman some distance in the rear, that the most careful investigation only resulted in the suspension of the brakeman for not having gone far enough back, but that he was now satisfied that the color blindness of the engineer had been the real cause of the accident.

It may be safely assumed that in the various emergencies of a railroad service, day and night, the year round, if an accident could occur from such and such contingencies, that it will be but a matter of time when it will become a verity.

Some slight or minor accidents recently led to the discovery that an engineer had by some oversight not been tested in his division, and this led to his examination and detection there, and to his conviction by the writer as color blind.

Still another case now presents itself: an engineer some time ago ran over and killed a brakeman holding a danger signal on the track in front of his engine, and no satisfactory explanation could ever be given, but the division examiner predicted that he would probably be found color-blind; on his examination this proved to be the case.

In a recent popular article on Control of Vision, Dr. Jeffries, who has done more than any one in this country to call attention to its dangers, laments the entire failure in Connecticut, and the partial failure in Massachusetts, to obtain efficient legislation to compel railroads to expel their deficient men. He tells us of the like condition of things in England, and finally adds that the Pennsylvania Railroad alone has availed itself of scientific advice. Perhaps if the system adopted by it had then been described and urged as most in keeping with our institutions, we might hope to see all the roads in the country following its example; but the advice which might be accepted, if proffered in a practicable manner, has been hitherto urged upon the officials by means of hostile newspaper articles, and agitation for legislation to place their entire signal force at the mercy of state-appointed examiners who might disorganize it and bring it into great confusion.

There seems to be a natural hesitation on the part of medical men to place the examinations for color-blindness in the hands of laymen, and an equal unwillingness on the part of railroad officials to submit their force to the inspection of a numerous corps of medical examiners. The solution is found in the use of the instru-

ments described, which merely enables non-professional persons to make a record of certain selections and place them on paper, where they can then be submitted to a surgical expert who can as well decide upon that evidence as though he were present at the examination, with the understanding that all suspicious cases are to be examined by him in person.

What is gained by this? The expense under the law passed in Massachusetts and Connecticut was estimated to be from two to three dollars per man, to be paid by the roads, and with a penalty for the employment of any man not provided with the certificate of an expert appointed by the Governor of the state. For this sum, say three hundred dollars per one hundred men, the road could be informed that ten to fifteen employés were unfit for its service; no provision having been made for the correction, by glasses or other treatment, of the trained men, otherwise so valuable, and no time being allowed to replace men especially fitted for certain duties; and the roads were to be thus taxed for the more than decimation of their entire force, whilst the employés were subjected to a pitiless scrutiny that would end in the summary dismissal of about fifteen per cent from the discharge of duties for which they had spent perhaps years of training. It can easily be understood why such a law would be resisted by all the political or other influences of the entire railway force in a state, from the directors and presidents to the lowest employés, and should awaken also the opposition of the holders of its securities.

By the system adopted on the Pennsylvania Railroad, the men below the standard are detected unerringly by their own officials; those color-blind are sent to the surgical expert and after his decision, are yet retained in the service where possible, being placed where their defects can work no harm. Any valuable man below the standard of visual power can be sent for treatment, if the officers so decide, or the men can elect to have their cases treated elsewhere upon the condition that they can pass the proper examination afterwards. The one plan, it is evident, is expensive, irritating to the whole personnel and disorganizing; while the other is economical, confidential and orderly. By a wise liberality in aiding men to have their acuteness increased by proper glasses the officers of the road have been able to carry out their wishes without any noticeable opposition from the employés, and have thus effected

for hundreds what would otherwise have cost them thousands of dollars, if any plan hitherto proposed had been adopted. Since only the color-blind and those needing surgical skill have been sent to the expert, he has not been in a position to give statistical tables of the examinations, and he therefore submits the following letter from Mr. Charles E. Pugh, the general manager, to substantiate his statements and bear witness to the success of the entire system.

PENNSYLVANIA RAILROAD CO.
*Office of the General Manager,*
233 *So. 4th St., Philadelphia, Pa., April* 26, 1884.

DR. WM. THOMSON,
Surgical Expert, Penn. R. R. Co.,
1426 Walnut Street, Philadelphia.

Dear Sir: The practical examination of our employés as to their acuteness of vision, color-sense and hearing, in accordance with the system proposed to us by you and carried out under your supervision, has been extended to all the various divisions of the Penn. Railroad, has embraced nearly all of the men engaged in duties requiring the use of signals now in the service and will be used hereafter in the selection of men placed on such duty, or in the employment of new men entering our service.

In approaching the completion of the task of examining those now in our service (more than twelve thousand employés having now been submitted to your system), I desire to express to you our entire satisfaction with the rules and regulations, tests and instructions prepared by you, as well as with the personal supervision instruction of examiners, and examinations and decisions upon doubtful cases and persons referred to you for final action.

Our division superintendents and their staff officers have been able to deal promptly with the great majority of defective men and thus avoid the necessity of availing themselves of that clause in the instructions which provides for an expert examination in each suspected case, and have in this way carried out your purpose without undue excitement among the men, in a speedy and confidential way, and with economy to the company.

The proportion of those defective in color-sense, vision and hearing was found by the examination of two thousand men before the adoption of this plan to be 4 per cent of the first and about 10 per cent of the latter, and I am satisfied from my reports that all those thus deficient are being relieved of duties which they cannot perform, and that the great dangers to the public and to the other employés of loss of life, and to the company of possible destruction of property, have been averted, so far as their defects are concerned.

I am frequently asked by prominent officers of other railways and government officials to give an opinion as to the practical usefulness of our

system of examination, and it affords me much pleasure to emphatically commend it in all its details; and I feel that we have good reason to be satisfied with this the first successful attempt to bring the entire body of men engaged in signalling upon a railway in our country, under control by the practical application of scientific facts. Having eliminated these dangerous persons from our present force we propose to keep it free from them in the future by a steady application of our present system.

Yours truly,

CHAS. E. PUGH,
*General Manager.*

To this great corporation, extending through six states, operating five thousand miles of track, with nearly if not quite fifty thousand employés, and responsible for the lives of millions of people each year, must be accorded the honor of having been the first to obtain the desired control of the visual defects of their men by a wise and intelligent application of scientific laws.

Their example has been extensively followed elsewhere and their instrument has been obtained by more than thirty other roads from the manufacturer. It has also been ordered by "The Board of Trade of England," by many distinguished medical men abroad, and has recently been, with the entire system, adopted and will no doubt, be put into operation by a director of the Southwestern Road in England. There is no longer any reason why losses of life and property should occur in railway service from visual defects; and an enlightened public opinion should now insist upon the adoption of some similar plan upon the hundred thousand other miles of railway now being operated in our country.

Having been placed as the American representative on the committee on Control of Vision at the International Congress in London three years ago, I have urged upon the Naval Committee of our Congress the value of this large experiment with a view to have a law passed to form an International Commission to establish a uniform system of signals, examinations, etc., both on the land and on the water. There is no doubt that accidents must occur on the sea, and the recent loss of the Tallapoosa has not only been ascribed to a wrong interpretation of the colored signals, but the commission appointed to investigate the accident have been especially directed to examine for color-blindness the lookouts on the ships.

NOTES ON ANEROIDS. By Prof. M. W. HARRINGTON, University of Michigan, Ann Arbor, Mich.

[ABSTRACT.]

1. The popularization of the barometer. This can best be done with the aneroid; fairly accurate ones should be retailed at a low price.

2. Improvements of the aneroid for accurate measurements. The three or four recent German modifications are briefly described and discussed.

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AN ABSOLUTE SENSITOMETER. By Prof. G. W. HOUGH, Director Dearborn Observatory, Chicago, Ill.

[ABSTRACT.]

VARIOUS methods have been employed for ascertaining the sensitiveness of photographic plates, but we do not know that any hitherto used are capable of giving directly the sensitiveness as referred to any convenient standard. The use of blackened gelatine films may give sufficiently reliable results, but from the nature of their construction, no two instruments will be precisely alike, and even in the same instrument there is no definite relation between the different parts of the scale.

The use of a series of tubes having unequal areas might answer under certain conditions, but such an apparatus would be complicated.

It occurred to me that if a perforated disk was made to revolve in front of a scale of numbers, the light received by each would be directly proportional to the angular opening in the disk. To illustrate, suppose we have a semicircular disk, which is made to revolve rapidly, then any number covered by it when in rotation would receive only one-half as much light as one outside of its circumference. If the disk revolves with sufficient speed both numbers will be constantly visible to the eye, but one will receive only one-half as much light as the other. On this principle is based the sensitometer about to be described.

Let any scale of numbers from 0 to 100 be photographed or painted on clear glass or the numbers may be engraved on a black-

ened glass plate. The plate to be tested may then be placed behind it, to make a contact negative. In front of the scale, the snail or perforated disk may be rotated so as to give each number its proper amount of illumination, the light being a standard candle at one foot distance.

If the time of exposure be one second, and the last number visible in the negative is two, the equivalent exposure will be

$$1 \times \tfrac{2}{100} = \tfrac{1}{50} \text{ sec.}$$

If another plate under the same condition shows the number 4 in the negative, its equivalent exposure will be $\frac{1}{25}$ second. The reciprocal of these fractions will be the direct measure of sensitiveness.

In other words, the apparatus will give the actual time required for the light of one standard candle at one foot distance to make a legible record, and this time is the standard of sensitiveness; the only source of error will be in the standard candle.

In testing rapid emulsion plates, it is desirable to place the standard candle at eight or ten feet distance, in order that the error in making the exposure may be reduced to a minimum.

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AN EXPERIMENT FOR ILLUSTRATING THE CONVERSION OF MECHANICAL ENERGY INTO HEAT. By Prof. CHAS. E. MUNROE, U. S. Naval Academy, Annapolis, Md.

[ABSTRACT.]

A PERFORATED cork having been attached to the arbor of a Griscom electro-motor, a test tube is inserted in the cork. A wad of gun cotton is placed in the test tube and the tube corked. On setting the motor in revolution, sufficient heat is generated to fire the gun cotton and blow the cork from the tube.

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ON THE VARIATION OF THE RESISTANCE OF CARBON UNDER PRESSURE. By Prof. T. C. MENDENHALL, Ohio State University, Columbus, Ohio.

[ABSTRACT.]

THE variation of the resistance of carbon under varying pressures has been made the subject of investigation by a number of phy-

sicists. The conclusion which seems to have been most generally reached was that such variations are due to changes in the surface contact of the poles with the carbon, rather than to any internal changes in the carbon itself. In April, 1882, the author had prepared an account of some experiments upon soft carbon, as used in Edison's Tasimeter, which was read before the National Academy and afterwards published in the Am. Journ. of Science, for July, 1882. In this paper he had ventured the opinion that variations in surface contact would not account for all of the observed facts.

This conclusion had been criticised by Professor Sylvanus Thompson who quoted experiments made by Professor Barrett and Mr. Herbert Tomlinson in support of his objections.

The matter had been taken up again by the author within the past few weeks and new experiments had been made to test the question. In these experiments mercury contacts had been exclusively relied upon.

In the case of hard carbon the pressure was not applied through the conducting contacts. The results of many experiments showed without a single exception, a diminution of resistance accompanying an increase of pressure. In this conclusion the author found himself supported by Mr. Herbert Tomlinson in a paper read before the Royal Society on the "Influence of stress and strain on the action of physical forces."

The soft carbon used was of the form previously referred to. The disk of carbon was confined between two bevelled glass tubes, so as to form a V-shaped apparatus, with the carbon held between the two branches at the vertex of the angle.

Pressure was applied by pouring mercury in both arms to any desired height, and connection with the mercury was made by means of platinum wires sealed in the tubes. Very decided results were obtained by varying the pressure upon the carbon. Other experiments were described in which the attempt was made to determine whether, under such circumstances, a variation in surface contact between the carbon and the mercury would occur, to a sufficient degree to account for the facts observed with the V tube. The results obtained were such as to convince the author that there was little doubt but that there existed a real change in the specific resistance of the carbon due to changes in pressure.

It was unfortunate, however, that the pressure, in this case, was

applied through the conducting faces of the carbon. It seems almost impossible to avoid this in the case of soft carbon, but the author proposed to continue the investigation and to remove, as far as was possible, every objection to the methods employed.

The so-called "crucial experiment" of Professor Barrett was referred to and it was shown to be faulty, in that the pressure had been applied to one face only of the carbon disk, and proper precautions had not been taken to insure the absence of air bubbles.

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A POSSIBLE METHOD OF ELECTRICAL COMMUNICATION BETWEEN VESSELS AT SEA. By Dr. A. GRAHAM BELL, Washington, D. C.

In a paper read before the American Academy of Arts and Sciences (Dec. 11, 1878)[1], I described a modification of a method of tracing equi-potential lines and surfaces employed by Prof. W. G. Adams[2] and other observers. The chief point of difference lay in the use of a telephone in place of a galvanometer, and in the employment of a rheotome, to interrupt the battery circuit with great rapidity. In this paper I described the following experiment which suggested to my mind the method now proposed as a possible method of communication between vessels at sea.

Take a basin of water, introduce into it, at two widely separated points, the two terminals of a battery-circuit which contains an interrupter making and breaking the circuit very rapidly. Now at two other points touch the water with the terminals of a circuit containing a telephone. A sound will be heard, except when the two telephone terminals touch the water at points where the potential is the same. In this way the equi-potential lines can easily be picked out. Now to apply this to the case of a ship at sea: suppose one ship to be provided with a dynamo machine generating a powerful current, and let one terminal enter the water at the prow of the ship, and the other be carefully insulated, except at its end, and be trailed behind the ship, making connection with the sea at a considerable distance from the vessel; and suppose the current be rapidly made and broken by an interrupter: then

[1] Proc. of the Amer. Ac. of Arts and Science; also Nature, Vol. XIX, p. 211.
[2] Phil. Mag., Dec. 1875, Vol. L, p. 548.

the observer on a second vessel provided with similar terminal conductors to the first, but having a telephone instead of a dynamo, will be able to detect the presence of the other vessel even at a considerable distance.

This idea has been tested on a small scale with very promising results. A small boat, containing an interrupter and several cells of Leclanché battery, was moored upon the Potomac River in charge of an assistant. I then proceeded down the river in another boat containing a telephone. The circuits were arranged as described above. At the farthest distance tried—which appeared from the map to be about one mile and a quarter—the sounds produced by the action of the interrupter were distinctly but feebly heard. The experiment was not so successful when tried in salt water. I have hitherto refrained from publishing these ideas, as Prof. John Trowbridge, of Harvard College, communicated to me a year or so ago a very similar method which had occurred to him independently, and which I hoped he would publish. As this has not been done, and as the whole subject appears to me to be of importance, I have, with the permission of Prof. Trowbridge, ventured to bring it before your notice. Prof. Trowbridge proposed to utilize his method as a means of preventing collisions in a fog. He believed that by suitable modifications the officers of a ship might not only be able to detect the presence of an approaching vessel before dangerous proximity had been reached but might also be able to determine its position.

As Prof. Trowbridge himself is present it will be unnecessary for me to describe his method in detail.

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ON THE INTENSITY OF SOUND. II THE ENERGY USED BY AN ORGAN PIPE. By Prof. C. K. WEAD, University of Michigan, Ann Arbor, Mich.

[ABSTRACT.]

IN a previous paper the subject of the energy of vibration in tuning forks has been considered; and now, passing to gaseous bodies, we have to consider the energy per second that must be communicated to an organ pipe to maintain its sound. The general method

is that described by Mr. Bosanquet (Phil. Mag. 1872) but the experiments are much more accurate.

I. Drawing a single stop on the organ eight keys were pressed and the volume of air used per second found: from this of course the leakage is deducted, and the product of the remainder by the pressure on the bellows gives the work done. This was repeated in various parts of the scale and with various stops. It is very clear from the results that the efficiency of pipes of different stops is very different, as organ builders well know, and that a reed pipe is far more efficient mechanically than a flue pipe.

II. Drawing all the nine stops of the great organ and pressing a single key, we find the relative work done in different parts of the scale. The results may be well expressed by an exponential curve whose ratio is found by least squares to be .59 for the octave in most cases. But the common organ-builders' rule is to make the 17th pipe half the diameter of the first; assuming here an exponential series, the diameter of the pipe an octave above the first would be the $\frac{1}{16}$ power of $\frac{1}{2}$ which equals .5946. We must conclude therefore that Töpfer's rule endorsed by Mr. Bosanquet, according to which the ratio should be exactly .50, is true neither theoretically nor experimentally.

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A PRELIMINARY NOTE ON THE ACTION OF ACIDS UPON IRON IN THE MAGNETIC FIELD. By Prof. EDWARD L. NICHOLS, University of Kansas, Lawrence, Kansas.

[ABSTRACT.]

WHEN iron in the magnetic field is destroyed by acids, a process is performed which may be considered equivalent to its withdrawal by mechanical means to a position of zero potential. Since in such a process energy must be expended, we might expect the heating effect of the reaction to differ within and without the field by an amount equivalent to the energy necessary to withdraw the iron mechanically to an infinite distance. The author has completed a series of preliminary experiments to determine the character and amount of this difference. An electro-magnet was placed with its poles beneath and in contact with the bottom of a small

beaker. Within the beaker were placed five grs. of iron filings and 100 cc. of aqua regia. A sensitive thermometer served to show the temperature of the solution.

It was found, contrary to expectation, that the rise of temperature was much greater when the magnet was in circuit than when it was not acting. For purpose of comparison the reaction was repeated many times alternately with and without the current, care being taken that the conditions save those due to magnetization were in all cases the same.

The average rise of temperature in fourteen consecutive measurements was:

Magnet acting, 63.°7

Magnet not acting, 48.°7

The author's assistant, Mr. W. S. Franklin, repeated these measurements with the calorimeter. The mean of ten measurements showed the number of thermal units per gramme of iron consumed, to be:

Magnet acting, 1288.8 Calories.

Magnet not acting, 1035.0 ,,

The heat produced in these reactions was less than that obtained by Andrews by the combustion of iron in chlorine (1745 calories). Whether the product is in both cases a mixture of $Fe_2Cl_3$ and $Fe_2Cl_6$ the ferric salt predominating when the magnet is acting, or whether, as has been suggested to the author, new salts are produced under the influence of the magnet, further experiments must determine.

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LOCAL AND TOPICAL WEATHER CARDS. By W. M. DAVIS, Harvard College, Cambridge, Mass.

BY employing a method of graphic transference, described in *Science*, Apr. 4, 1884, two sets of cards are prepared: one showing the various kinds of weather experienced at certain selected stations, as controlled by distance and direction from the temporary, dominating region of high or low pressure; the other showing the distribution of certain single features of weather gathered from many stations and grouped in their proper attitude with respect to centres of high or low pressure. The first of these serves to discover what modifications of the general weather forecasts are needed for the stations for which they are applied. The second illustrates the limitation of certain phenomena, such as tornadoes, to relatively small parts of their parent cyclones.

## On a proof of contact theory of electricity. By Prof. A. E. Dolbear, Tufts College, Mass.

[ABSTRACT.]

Proof consists in employing a magneto telephone which is connected to a wire whose ends consist of plates of different metals, *e. g.*, zinc and carbon, or copper. These plates are then made to touch each other. Each touch may be heard, and if one terminal of the wire vibrates, like the prong of a tuning fork, against the other terminal, the rate of the vibration can be heard; thus showing the electrification and discharge by contact.

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## On comparative cost of electric light and oxy-calcium light. By Prof. A. E. Dolbear, Tufts College, Mass.

[ABSTRACT.]

This paper assumes an expenditure of 3 cu. ft. of oxygen per hour for oxy-calcium light and the amount of energy represented by that amount of oxygen. It gives the mechanical equivalent and horse power, represented by 3.4 horse power [illegible] candles. Same amount of electric energy [illegible] about 200 candle power and a [illegible] about [illegible].

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[illegible]

[ABSTRACT.]

[illegible]

## TITLES OF OTHER PAPERS READ IN SECTION B.

ON THE DISTRIBUTION OF POTENTIAL IN CONDUCTORS EXPERIENCING THE ELECTROMAGNETIC EFFECTS DISCOVERED BY HALL. By Sir WILLIAM THOMPSON, University of Glasgow, Scotland.

ON A STANDARD TANGENT GALVANOMETER. By Prof. SILVANUS THOMPSON, University College, Bristol, England.

ON THE GOVERNMENT OF ELECTRIC MOTORS. By Prof. SILVANUS THOMPSON, University College, Bristol, England.

CHANGE IN RAINFALL OF VIRGINIA. By J. R. PURDIE, M. D., Smithfield, Isle of Wight Co., Va.

THE PRINCETON METEOROLOGICAL OBSERVATORY. By Prof. WILLIAM LIBBEY, jr., Princeton, N. J.

A FORM OF APPARATUS FOR DETERMINING THE DIATHERMACY OF AIR AND GASES. By JOHN R. PADDOCK, Stevens Institute, Hoboken, N. J.

A PROPOSED METHOD OF DETERMINING THE MAGNETIC DIP BY MEANS OF A MAGNETIC PENDULUM. By MARCUS BAKER, U. S. Coast and Geodetic Survey, Washington, D. C.

DESCRIPTION OF A GALVANOMETER FOR DEMONSTRATING THE INTERNAL CURRENT TRANSMITTED THROUGH THE LIQUID WITHIN A VOLTAIC CELL. By CONRAD W. COOKE, C. E., Westminster, Eng.

THERMAL BELTS. By Prof. J. W. CHICKERING, jr., Deaf Mute College, Washington, D. C.

GEOMETRICAL METHODS IN THE THEORY OF REFRACTION AT ONE OR MORE SURFACES. By Prof. JAMES LOUDON, University College. Toronto, Canada.

SOME RELATIONS OF POSITIVE AND NEGATIVE ELECTRICITY. By Dr. H. W. EATON, Louisville, Ky.

A METHOD OF DISTRIBUTING WEATHER FORECAST BY MEANS OF RAILROAD TRAINS, ETC. By JOHN A. MILLER, Cairo, Ill.

NOTE ON THE PERIODIC MODIFICATION OF ELECTRO-STATIC INDUCTION. By Prof. H. S. CARHART, N. W. University, Evanston, Ill.

ON THE SENSITIVENESS OF THE EYE TO COLORS OF A LOW DEGREE OF SATURATION. By Prof. E. L. NICHOLS, University of Kansas, Lawrence, Kansas.

A SPECTROPHOTOMETRIC STUDY OF PIGMENTS. By Prof. E. L. NICHOLS, University of Kansas, Lawrence, Kansas.

FIRST STEPS TOWARD A GENERAL SYSTEM OF OBSERVATIONS OF ATMOSPHERIC ELECTRICITY. By Prof. CLEVELAND ABBE, Washington, D. C.

ORGANIZATION OF SEISMOLOGICAL OBSERVATIONS. By Prof. CLEVELAND ABBE, Washington, D. C.

METHODS OF VERIFYING WEATHER PROBABILITIES. By Prof. CLEVELAND ABBE, Washington, D. C.

STANDARDS OF BAROMETRY AND THERMOMETRY. By Prof. CLEVELAND ABBE, Washington, D, C.

ON THE ROTATION OF THE EQUIPOTENTIAL LINES OF AN ELECTRIC CURRENT BY MAGNETIC ACTION.[1] By Dr. E. H. HALL, Instructor in physics at Harvard College, Cambridge, Mass.

[1] Printed in full in the American Journal of Sciences, Vol. XXIX, Feb., 1885.

SECTION C.

# CHEMISTRY.

# ADDRESS

BY

## PROFESSOR JOHN W. LANGLEY,

VICE PRESIDENT, SECTION C.

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FELLOW MEMBERS OF THE CHEMICAL SECTION:

LADIES AND GENTLEMEN:

IN reviewing the history of each living being and of every intellectual conception, we are at once made aware of a law of growth the most general and fundamental possible, namely, that of development, or progression along what often seems to be a predetermined line whose constraining influence is so powerful that it is only by following it that the organism can escape destruction.

Development, while it may be continuous, both for the individual and for the race when broadly looked at over large intervals of time, is, on the other hand, a process which, in its details, is constantly interrupted both by alterations of direction and by arrests of action which may even go so far as to cause retrograde metamorphoses.

A plant may readily grow unsymmetrically if shaded on one side; but that error of form will be largely corrected when it is again bathed with light which comes from all directions. This partial arrest may even arise from the plant itself, as when the excessive growth of the vine in forming new wood saps the energy which should go to the formation of fruit, and the grapes, which alone make the plant valuable to man, never reach that fullness and flavor which should recompense the toil of the husbandman.

All of us here are constituent intellectual atoms in a great ideal organism called Chemistry. We know the long and honorable history of our science; we know, too, its wonderful progress in the past fifty years; we perceive how from the single stem of Alchemy it has thrown out branches in all directions, mineral, organic,

analytical, synthetic, agricultural, physiological, biological chemistries; but has it furnished a corresponding number of great far-reaching laws? Has it been equally prolific of grand hypotheses which have stood the test of time?

Will you pardon me if I venture to apply the analogy of the plant, and to ask whether our development has been symmetrical, whether some struggling bud put forth in our youth has not been starved and shaded by the abundant leafage of our branches, and whether in the rapid accumulation of facts from that great diffused solution of them called Nature, while we may have greatly increased our quantities of chlorophyll and cellulose, we have equally gained in the fruit, whether we have been equally successful in elaborating well-rounded generalizations which fill the intellectual taste with a sense of delight, and which stand forth as the declared fruit of our toil.

Such a bud our science put forth in its alchemical stage under the name of affinity. During the early part of the present century the idea received considerable expansion and showed, at one time, a vitality comparable with the condition of the doctrine of the conservation of energy prior to the year 1850. Having reached this stage the development of a theory of affinity seems to have been arrested and soon it is seen occupying a position of constantly decreasing interest to chemists. The proof of this statement is easily found by comparing such works as Daniel's Introduction to Chemical Philosophy, Thompson's History of Chemistry and Daubeny's Atomic Theory, published in 1830 and '31, or the works of Berzelius, with any recent manual of inorganic chemistry. In the older books the amount of space given to the treatment of chemical affinity is relatively large, while in the treatises of to-day it is in many cases hardly even mentioned.

In the article Chemistry in the new Encyclopædia Britannica, covering 120 pages, there is not a single paragraph referred to the title affinity, and less than half a page devoted to it indirectly. In Watts' Dictionary of Chemistry, including the supplements, out of a total of 9665 pages, only 62 are devoted to affinity where it appears under the head of chemical action. In Wurtz's Dictionnaire de Chimie, the treatment of affinity under the several heads of chaleur, electro chimie, affinité, atomicité, etc., is relatively fuller, but still the proportion is quite small, and in that excellent manual Remsen's Theoretical Chemistry, the second edition of

which was published last year, the word affinity does not even occur in the index. The causes of this almost complete abandonment of a word, and an hypothesis at one time considered of fundamental importance, can best be traced by reviewing briefly the history of that part of speculative chemistry which is related to the doctrine in question; a review which will show us that it is the word only which has become obsolete, the idea behind it is still active and of great importance. I will, therefore, venture to ask your attention to what I am only too well aware is but a sketch of the development of theories concerning the nature and fundamental cause, or causes, of chemical phenomena.

## I. *The Conception of Affinity.*

The earliest appearance of the idea which has since been named chemical affinity is found in the writings of Hippocrates in the fifth century B. C., where the opinion is expressed that when two bodies unite to form a compound, a certain common principle must indwell in them, for it is laid down as a fundamental postulate that "like unites only with like," hence the two bodies must possess some common principle, or have a bond of kinship between them.[1]

This conception prevailed with more or less clearness for several centuries, but it is not till the year 1698 that we find the word *affinitas* employed and defined. It first occurs in the writings of the alchemist Barchusen,[2] and the conceptions of Hippocrates were still the ruling ones. Thus Barchusen explains the impossibility of completely isolating the four elements by saying that they have for each other a strong affinity which causes one to mingle with another, and which cause is derived from a principle common to them all.

Boerhaave, the celebrated physician of Leyden, in his elements of chemistry, which appeared about 1732, was the first to extend the meaning of the term *affinitas or Verwandtschaft*, since he says, "The effort also of like substances to unite is due to the working of the same force;"[3] and elsewhere in explaining the cause of solution, he says, "In this last case" (that of the action of aqua regia on gold), "why do not the particles of gold, which are nineteen times heavier than the particles of aqua regia, collect together in the bottom of the vessel? Do you not see clearly that there is between each particle of gold and each particle of aqua regia a

force in virtue of which they seek each other out, unite and retain each other?"[4] We also notice in Boerhaave's writings a tendency to regard combination as due to the attraction of opposite, rather than to the union of similar qualities; for he compares the action of an acid upon iron to a marriage, and says that the combination comes rather from love than hate.

Two of Boerhaave's successors, St. F. Geoffroy and Torbern Bergman, appear to be the authors of a new conception which was subsequently known under the name of elective affinity. Geoffroy attempts to indicate the order of chemical actions, or, as we should now call it, the relative intensity of combining power, by arranging several bases in the order in which they displace each other. Thus one of his tables was the following:

| Vitriolic Acid.[5] |
|---|
| Sel alkali fixed. |
| Sel alkali volatile. |
| Earths. |
| Iron. |
| Copper. |
| Silver. |

It was soon discovered, however, that an order of bases which might be correct for one acid would be incorrect for another, and that a given substance would take different positions in the two.

The following, which is a portion of one of Bergman's lists, published in 1783, will show the fact.[6]

| Gaseous Acid. (Carbonic). | Acid of Sugar. (Oxalic). |
|---|---|
| Pure heavy earth. | Lime. |
| Pure lime. | Heavy earth. |
| Fixed vegetable alkali. | Magnesia. |
| Fixed mineral alkali. | Fixed vegetable alkali. |
| Magnesia, etc. | Fixed mineral alkali, etc. |

The reversal of the order of attraction was explained by assuming the existence of preferences or special attractions between acids and certain bases and was known under the name elective affinity, a term which has remained in chemical literature till quite recent times, and, indeed, was very generally used within the recollection of most of us here present.

The chemist Glauber, 1689, was one of the first to recognize this fact of differential attractions. He teaches[7] that "potash, lime and zinc oxide, with application of heat, drive out ammonia from sal ammoniac because the zinc, as also potash and lime, is of such a nature that it has a great community of interest with all acids, loves them and is also loved by them; accordingly when warmed, the acid of the salt (muriatic) attaches itself to it, combines with it so that the sal volatile is set free and is distilled to a subtle spirit."

The next advance in the direction of precision was made by Wenzel, who,[8] in a work entitled *Lehre von den Verwandschaften* published in Dresden in 1777, showed that when two neutral salts act upon each other by double decomposition, the new salts formed are also neutral and thus prove chemical unions to be governed by some general law which determines how much of one acid must be taken to displace another. Although Wenzel's work attracted but little attention at the time, we can now see on looking back that it marked a very important discovery, for he must be regarded as the first man who apprehended with any distinctness that fundamental law of chemistry, definiteness of action, which was subsequently enunciated and is familiar to us to-day under the name of the "law of definite proportions."

The final result of Wenzel's discovery was the establishment of the law of equivalent proportions through the labors of Richter, Thompson, Wollaston, Berzelius and others, and from equivalent proportions sprang the Daltonian hypothesis of atoms which has developed into the all but universally accepted atomic theory of the present day.

The atomic theory, however, is not necessarily coterminous with hypotheses about affinity, and indeed in many respects it is independent of them; the development of its history is therefore foreign to the purposes of this paper, but if we turn back to the period which immediately follows Wenzel's discovery, which was that of the re-birth of the atomistic theory of the Greeks under Dalton's parentage, we see that it emerged from opposing views about the nature of affinity, and at this point, therefore, the two speculations have a common history. The opening of the present century witnessed an active controversy between the advocates of the new, or equivalent and atomistic school, and the partisans of the older philosophy. Prominent among the latter stands

Berthollet who was a consistent and earnest opponent of the new doctrines. In his well-known work *Essai de Statique Chimique*, published in 1803, he maintains the proposition that all unions are caused by the joint action of two forces which are opposed to each other, cohesion and elasticity. He denies entirely that the union by equivalent or definite proportions is a fact. In opposition he brings forth his celebrated theory of mass, according to which, combination occurs under the influence of cohesion and in proportion to the masses of the reacting bodies, being directly proportional to these two forces and inversely proportional to the elasticity or volatility. Berthollet considers that there is no distinction of kind between chemical union and mixture except that in the first the action of cohesion is more apparent. He says[9], "The force of cohesion is often a cause which determines combinations. Whenever there is produced some solid substance, whether by a separation or by a combination, we must look in the reciprocal action (cohesion) of the parts which require solidity for the cause which produces it, although it did not manifest itself previously. Alkalinity and acidity have no influence on the reciprocal action of salts which are in the neutral state, but all the phenomena which they produce must depend on the properties which emanate from the reciprocal action of their integral parts. In the mixture of liquid substances (neutral) those combinations which ought to act with a force of cohesion capable of separating them ought to be formed and separated in fact."

The position assumed by Berthollet was, of course, finally overthrown by the improvements in methods of analysis on the one hand, and by the Daltonian theory of atoms on the other; but it is a noteworthy fact that it is only as a complete and universal explanation of chemical action that Berthollet's theory fails. In many respects his position still holds good, and his views on the influence of mass are now being revived and partially confirmed by researches made within the present decade.

The progress made in the allied science of physics now begins to react on chemical studies, and we find the subject of electricity, which was opened by Galvani and Volta, taken up and pursued by men who are eminent both as electricians and as chemists. Davy in 1807 and later, more fully in 1826,[10] introduced the electrical theory of the nature of chemical affinity, and stated that "chemical and electrical attractions depend upon the same cause, acting

in one case on particles, in the other on masses of matter." His contemporaries and successors, Oerstedt, Grotthus, Ampère, Becquerel, Berzelius and Faraday, amplified and extended the electrochemical theory. Grotthus contributed his well known hypothesis of liquid polarization; Ampère considered that each atom is surrounded by a special atmosphere of electricity, positive and negative, and that combination of atoms occurs by the neutralization of the opposing atmospheres. Berzelius held that the atoms have poles. He says,[11] "Affinity is only the effect of the electrical polarity of the particles; electricity is the primary cause of their chemical action; it is the source of the light and heat disengaged during combination;" and, finally, Faraday's immense contribution to electro-chemistry is too well known to need any further mention here.

Notwithstanding this array of great names, and the stores of experimental knowledge contributed by their owners, electrical hypotheses do not seem to have added much that is valuable to the theory of chemical action except in one respect, which, however, is a fact of the utmost importance, namely, that whenever combination or decomposition takes place, the corresponding decrease or increase in value of the affinity involved is revealed as a definite and measurable amount of energy, which may be either electrical, thermal or mechanical.

We have by this theorem a mode of measuring affinity quantitatively; but electrical theories do not establish the *nature* of this force beyond dispute, and this is shown by the fact that the English school of electricians, under the leadership of Sir William Thompson, have for some years been divided in opinion as to the sources of the current developed by the Galvanic battery, between the old contact theory of Volta and the chemical theories of Davy and Faraday. While the electro-chemical theory was being developed the founders of the atomic theory were not idle, and in that wonderfully fruitful decade which witnessed the enunciation of Dalton's views, we find also the nucleus of an idea which has an important bearing on the nature of affinity.

In 1811 Avogadro[12] formulated that law which is now regarded as the strongest bolt in the framework of the atomic theory; but in stating his conclusions in regard to the number of "elementary molecules" in equal volumes of gases he necessarily introduced the conception of what is now the fundamental distinction between

atoms and molecules, and its later development into our belief in the two orders of combination, atomic and molecular. This theorem, of the utmost importance to the atomists, cannot however be considered as a material contribution to the theory of affinity, because the actions of this force are experimentally evident and are, therefore, not dependent for their verification on the molecular theory; but the form which this idea subsequently took in the mind of Brodie was, on the contrary, of the highest importance, for it is essentially a *new* conception.

In his paper entitled "On the state of the elements at the moment of chemical change,"[13] this chemist regards the molecules of elementary bodies as composed of atoms. The difference between the action of an element when free and when combined is due chiefly to the fact that when free the element is combined with itself in the form of an integral molecule. He says, "The general object of the paper may be considered as to prove that, at the moment of chemical change, the same chemical relation exists between the particles of which certain elements consist, as between the particles of compound substances under similar circumstances, on which relation the phenomena of combination and decomposition depend; that in short (to use common language), the particles of the element have a chemical affinity for each other." It is true that Brodie's terminology is drawn both from the atomic and from the electro-chemical theories, for he uses the expression "polar relation" instead of chemical affinity, but his idea is actually independent of these hypotheses; for what he really shows is that an element may combine with itself. What is new and original in his conception is that affinity can be exerted by one portion of an element on another portion of the same element, and hence there is no distinction of kind between the attraction of a body for other substances and its attraction for itself. This must certainly be regarded as an important extension of former ideas about combination. How fertile it is, we see in its application to the structural formulæ of the organic chemistry of to-day.

There remain three discoveries which have brought modifications into the older conceptions of affinity. They are, 1st, The influence of structure or position; 2nd, The subject of valence; 3rd, The periodic law applied to the elements. Two of these discoveries are, compared with the long history of the science behind them, almost affairs of yesterday. All of them are now subjects of de-

bate and controversy, and they have taken their present form, rather from the nearly simultaneous labors of many chemists, than from the projecting force of a single brain.

To trace the history of these doctrines would be difficult; to apportion justly the share of merit belonging to each contributor would be impossible, for we are now in the midst of the struggle, conflict and change, which mark the progress of every living idea, in the same way that they are necessary accompaniments of every vital organism.

It is too soon, therefore, for any one to know what part is destined to remain and what to perish.

The germ of the idea, that the position of an element in a compound influenced profoundly the ordinary behavior of that element, originated on the one hand in the theory of radicles, which owes its origin to De Morveau, 1787, Berzelius, 1817, and especially Liebig, 1832; and on the other, in Dumas' discovery in 1834 that chlorine could be substituted for hydrogen. Although the term radicle as now used means something quite different from Liebig's radicle, it is certain that our present conception of acids, as bodies which can be divided into hydrogen and an acid radicle, is justified only from the discoveries of those chemists. It is unquestionably true that in acetic acid, $HC_2H_3O_2$ we have hydrogen in two distinct positions, or, if I may be allowed the expression, two kinds of hydrogen: one, the basic, replaceable by a metal; the other, that within the acid radicle, not displaceable by a metal, but easily removable by chlorine; and further, the substituted chlorine will have lost its familiar characteristics: for example, it will no longer precipitate silver, but will, on the contrary, assume a part of the duty previously borne by the hydrogen in the new acid, chloracetic, thus formed. Evidently we have here shown to us a new property of elements brought out by the facts of substitution, and shown with equal distinctness by the facts of isomerism. It does not arise from the particular symbol selected, or from the expression atom and molecule. If the atomic theory were abandoned to-morrow, the above indicated experimental differentiation of hydrogen into two states or kinds would receive our rational indorsement, though all our vast wealth of atomic expression had perished.

The invention of the term valence, or atomicity, is generally credited to Adolph Wurtz, but the idea behind the names grew up

so gradually from the theory of types, from the study of radicles, and from the controversy on the cause of etherification and also from the labors of Laurent, Gerhardt and Sterry Hunt, that it is hardly prudent to assign any specified year as the exact date of its origin. The "periodic law" is customarily associated with the name of Mendelejeff,[14] and modifications in the form of the law with that of Lothar Meyer.[15]

There is also an English chemist, J. Newlands,[16] who claims to be the originator of the discovery, his speculations being published in 1864, while Mendelejeff's did not appear till 1869. Both of these conceptions, valence and periodic law, are immediate outgrowths of the atomic theory. The value assigned under them, and even their very form, depend absolutely on our choice of the numbers expressing atomic weight; for instance, the distinction between monad chlorine and dyad oxygen wholly disappears when the old symbols, HO for water, and HCl for hydrochloric acid are employed. It is an open question whether valence has any proper connection with affinity. Many chemists make an absolute distinction between them; moreover, the doctrine of atomicity is so preëminently a living issue of to-day that any discussion of it here would be out of place.

Finally, I will close this review with a condensed statement of the principal theories of affinity, taken from Watts' Dictionary.[17]

1. "*Chemical combinations are produced by universal attractions.*"

The most noted adherents of this view are Newton, who considered affinity as identical with the force of gravitation, and Berthollet, who held it to be the same as cohesion.

2. "*Chemical combinations are produced by a peculiar power called affinity, distinct from universal attraction.*"

Under this head we may place the alchemists and the believers in elective affinity.

3. "*The union of heterogeneous atoms is the result of electrical attractions.*"

This includes Davy, Ampère, Berzelius, and perhaps Faraday.

4. "*Chemical action results from a constant motion among the ultimate particles of bodies, this same movement likewise giving rise to the phenomena of heat, light and electricity.*"

This is Williamson's theory of incessant atomic interchange between all molecules in solution. The same hypothesis has also been sustained by Kekulé and Michaelis.

The above closes this very imperfect sketch of the growth of the *conception* of affinity, but it ignores the important dynamic problem connected with it.

Let us turn our attention to the questions of force and energy which form so important a part in the history of every chemical change.

## II. *Quantitative Measurements of Affinity.*

The earliest attempts to measure the strength of affinity appear to be those of Geoffroy and Bergman by arranging the several bases in the order in which they combine with a given acid, or, as we should now say, in the order in which they replaced each other. Illustrations of these tables have already been given, and it was apparent at a glance that the elective affinity so measured could at best be only relative to some one reaction arbitrarily chosen, and that the strength of attraction, as shown by the order in which the bases were arranged, was variable and depended on the nature of the acid selected.

These tables were amplified and improved by Young and Richter, the latter of whom, in his work published in 1792,[19] gave numerical values for what he calls the capacities of saturation which belong to the several acids and bases. These numbers, however, do not express the strength of chemical action in terms of force but rather the weights of the several bases which combine with an acid; they are, therefore, primitive determinations of equivalent weights, and hence they belong more to the history of the atomic theory than to that of affinity.

In referring to the law of Avogadro I said that while he introduced the distinction between the two kinds of "elementary particles" from which have since come our existing beliefs in the two kinds of union, atomic and molecular, still his proposition could not be considered an important contribution to the theory of affinity while it rests for its validity on the language of the atomic theory. The proof of this conclusion will be evident when we consider that the same discrimination between the two kinds of chemical action was very clearly foreshadowed from speculations concerning the value of chemical attractions before Dalton's hypothesis was given to the world.

An English chemist, William Higgins, professor of chemistry to the Dublin Society, published, in 1789,[20] a work in which the

composition of several bodies is attributed to the union of "ultimate particles," sulphurous acid being formed of one particle of sulphur and one of oxygen; "nitrous air" of two particles of dephlogisticated air and one of phlogisticated air, etc. He assumes that the attractions between iron and phlogisticated air (oxygen) may be expressed by a certain number, seven, for example; that the force between sulphur and phlogisticated air will then be represented by six and seven-eighths; finally, that the iron will also attract the sulphur and the oxygen not already combined with itself, by the feebler force of two. Now, under these conditions, the iron cannot break up the sulphur compound, nor the sulphur the iron compound, but both the phlogisticated iron and sulphur will be united into a compound system by this residual force of two, existing between the groups. This is exactly what would be represented by the equivalent symbol for ferrous sulphate, FeO, $SO_3$, where the oxide of iron, FeO, and the sulphuric acid, $SO_3$, were each regarded as entire or binary compounds united to form the ternary body, FeO, $SO_3$. Shortly after these attempts of Higgins, we find, in the opening years of the present century, three general methods indicated for the study of the force of affinity. Instead of being successively taken up and abandoned, like all preceding speculations, they have remained steadily in use during the eighty years which have intervened, and they are to-day still the most promising means at our disposal. These three methods may be called the thermal, the electrical and the method of time or speed. It will be convenient to consider each one separately.

The thermal method was first indicated by Lavoisier in a memoir, a portion of which will bear quotation. He says,[21] "The equilibrium between the heat which tends to separate the molecules and their reciprocal affinities which tend to reunite them can furnish a very precise means of comparing affinities with each other; if we mix, for example, at any temperature below zero (Centigrade), an acid with ice, it (the acid) will melt it until it is so enfeebled that its attractive force on the molecules of the ice becomes equal to the force which makes these molecules adhere to each other, and which is so much the greater as the cold is more considerable; thus the degree of concentration at which the acid will cease to dissolve the ice will be so much the greater as the temperature of the mixture is lowered below zero, and we can refer to the degrees

of the thermometer the affinities of acids for water according to various degrees of concentration."

This method, indicated by Lavoisier, would seem to be a promising one, but it has never been followed, so far as I know, by any body unless it may be by Guthrie in his investigation of cryohydrates.[22]

The study of the heat enveloped when various elements unite with each other and when acids combine with bases has been pursued by many observers. The literature of the subject is already large and it now constitutes a very important branch of our science under the title of thermo-chemistry. Early pioneers in this field were: Thomas Andrews, 1844,[23] Thomas Woods, 1851,[24] Favre and Silberman, 1853,[25] J. Thomsen, 1853,[26] M. Berthelot, 1864 and Alex. Naumann.[27]

The work of Thomsen entitled "Thermo-chemische Untersuchungen," in three volumes, published at Leipsic in 1882, and that of Berthelot, "Essai de Mechanique Chimique" in two volumes, Paris, 1879, are models of painstaking and exhaustive research. By the labors, chiefly of these two men, we now know the thermal values corresponding to many thousands of chemical reactions. We have learned that the energies of a reaction which can be brought about in two methods, either in the dry way or by solution, differ in the two cases; that salts in solution are in a partial state of decomposition; that the attraction of a polybasic acid radicle is not the same for the successive portions of base added, and that the behavior of a mono-basic acid in solution differs essentially from that of a dibasic or tribasic acid.

The most important generalization to be drawn from thermochemical phenomena is that the work of chemical combination, or the total energy involved in any reaction, is very largely influenced by the surrounding conditions of temperature, pressure and volume, and the conclusion they force upon us in regard to the nature of affinity is most important, namely, that this force in accomplishing work is dependent, like all other forces, on the conditions exterior to the reacting system which limit the possible amount of change. Affinity is therefore at last definitely removed from the category of those mystical agents so often invoked by our predecessors in a less critical age as belonging to the causes which had no correlation with the general forces of nature.

Under the title *Dissociation*, St. Claire Deville gave to the chem-

ical world in 1857,[28] a new and fruitful method of investigating the nature of compounds. By determining the temperature at which bodies break up or are dissociated, he was able to perform a purely analytical operation on them not complicated by the introduction of any extraneous form of matter, and, since the gradual increase of temperature can be closely adjusted and watched, we have, in the process of dissociation, the perfection of an almost ideal analysis.

The laws developed by Deville and his successors in this field show us, that, after the point is reached at which decomposition commences, the further breaking up is determined by the pressure of the evolved products of the reaction, so that the permanence of the body depends on the magnitude of the two variables, pressure and temperature, either of which may be varied at will through a wide range. Deville thus gives us a fundamentally new mental tool with which to attack the problem of affinity by showing the close parallelism between chemical decomposition and the ordinary evaporation of a liquid at its point of maximum tension.

The electrical method of dissecting chemical forces has been followed less actively than the thermal one. Besides the well known experimental contributions of Davy, Becquerel and Faraday, many other more recent workers have studied the chemical changes of the battery and the electrolytic cell. Among these may be mentioned Joule's researches on the heat absorbed during electrolysis, and especially the work of C. R. Adler Wright on the "Determination of Affinity as Electromotive Force," in the Philosophical Magazine for 1880, 1881 and 1882.

The general outcome of these researches is that the products of electrolysis are so numerous and so varied by the results of secondary actions, that it is very doubtful whether the electromotive force measured is that due solely to the union of those atoms which are indicated by the principal equation of the reaction.

The method of time or speed of chemical reactions has a history as old as that of its two associates, but the story is much less eventful for very little work has been done in this field. Wenzel held that the affinity of metals for a common solvent, such as nitric acid, was inversely as the time necessary to dissolve them, the attacked surfaces being equal and invariable. He experimented on small cylinders covered with wax except on one of their bases.[29]

The most notable work in this field has been done by Gladstone

and Tribe[30] by ascertaining the rate at which a metallic plate could precipitate another metal from a solution; also by Berthelot, Menschutkin and others who have studied the time necessary for etherification. The rate of inversion of cane sugar has been investigated by Urech, and in this country by R. B. Warder.

The above are only three out of many subjects which have been studied in regard to their time rate. An index to the literature of this subject has been made by one of the members of this section, Prof. R. B. Warder, and may be found in the Proceedings of last year.[31]

To these general methods for studying the problems of chemical dynamics should be added the investigation of the action of mass, by Gladstone, in his well-known color work on the sulphocyanide of iron;[32] of the chemical action of light by the late J. W. Draper[33] in this country, and Prof. H. E. Roscoe[34] in England, as well as Becquerel[35] in France, pioneers who since have been followed by a host of students of scientific photography.

In the review just given no attempt has been made to do more than glance at the important contributions to the theory and methods of measuring affinity. Many names have been passed by and much work has been necessarily ignored owing to the limits of time and space which surround the writer of an address like this; but, notwithstanding the presence of those limits, and my consciousness of how greatly your patience has been drawn upon, I will venture to add a few words on one other phase of the subject, and that is

## III. *The Existing Problem.*

The history of the various modifications and additions which have been made to the primitive conception of the nature of affinity, when briefly summarized, appears to be this:

Hippocrates held that union is caused by a kinship, either secret or apparent, between different substances.

Boerhaave believed affinity to be a *force* which unites unlike substances.

Bergman and Geoffroy taught that union is caused by a selective attraction and therefore they called it "elective affinity."

Wenzel and his successors showed that affinity is definite in action and amount. It has limits, or proceeds *per saltum*.

Berthollet contended that affinity is not definite; he proves that

it is often controlled by the nature and the masses of the reacting bodies.

Dalton, Berzelius, Wollaston and others held, on the contrary, this force to be definite and to act *per saltum*. It is a power which emanates from the atom.

Davy, Ampère and Berzelius believed affinity to be a consequence of electrical action.

Avagadro in one way, and Brodie in another, show us affinity exerted by molecules as well as atoms; it is a force which binds together, not only particles of the same substance, but also of heterogeneous substances.

From the fact of the actual existence of radicles, and from the phenomena of substitution was developed the notion of position, and that therefore affinity varied with the structure of the body as well as with its composition.

The [illegible] between the number of atoms which are equal to [illegible] replacing power have led to the doctrine of valence, [illegible] shows that [illegible] its power [illegible] power of being [illegible]

gions of the mysterious and the unknown. When we look for an advance in precision of ideas, for a logical development of a satisfactory theory, or for generalizations which shall help us better to classify chemical phenomena in terms of force and energy, we are compelled to admit that the years have not brought the theory of affinity to a state of active growth; rather it is like that strange counterpart of a living tree, the branching coral, whose many busy workers do indeed each for themselves add their mites to the accretions of past generations, but who have failed with all their toil to infuse that mysterious principle which would make of their labors a living organism ruled by an internal law of growth.

Affinity, under its own name, is no longer presented in recent manuals. Chemists have more and more turned their attention to details, to accumulating methods of analysis and synthesis, to questions of the constitution of salts, to discussions about graphic and structural formulæ, and to hypotheses about the number and arrangement of atoms in a molecule; but they have not, until quite recently, made systematic attempts to measure the energies involved in reactions. Why? I believe the answer can be found mainly in two reasons. First, the word affinity is in bad odor; it dates back to the time when men mistook wild guesses for ascertained facts; when they knew not the distinction between physics and metaphysics, and when a plausible but flexible *occult* cause was a more welcome guest to a philosopher's brain than a stiff, hard fact. We see how enormously complicated the phenomena of chemical action have become, and we have lost all faith in hypotheses which can be evolved by the mere force of metaphysical introspection. Therefore, we are afraid to retain a name which once belonged to an idea now long buried in the limbo where so much scholastic rubbish has been consigned, and hence all the facts belonging to affinity are given under separate heads, and thus they lose the great advantage of being bound together under one title.

Secondly, there is a more important reason arising from what has hitherto been the traditional scope of our science.

Natural philosophy early sought the aid of Mathematics, and so laid the foundation for the comprehensive physics of to-day. Astronomy has always dealt with number, and hence stands as the best type of an exact science. Mechanics, in its analytical form is little else than a material embodiment of algebra and geome-

try. Chemistry alone of the physical sciences has offered no foothold to mathematics, and yet all her transformations are governed by the numbers which we call atomic weights. What is it which causes Chemistry, so preëminently the analytic science of material things, to be the only one of her group which does not invite the aid of Mathematics, the great analytic science of immaterial things?

It is because three fundamental conceptions underlie physics, while only two serve the needs of the chemist.

If I may borrow an analogy from geometry, I would say that physics is a science of three dimensions, while chemistry is a science of two dimensions. In the first, nearly every transformation is followed by its equation of energy and this involves the concepts space, mass, time; while in the second, an ordinary chemical equation gives us the changes of matter in terms of space and mass only; that is to say, in units of atomic weight and atomic volume.

Imagine for a moment what physics would be to-day without those grand generalizations, Newton's theory of gravitation, Young's undulatory theory of light, the dynamic theory of heat, the kinetic theory of gases, the conservation of energy and Ohm's law in electricity! Every one of these, except the last, is a dynamic hypothesis and involves velocity, that is, time, as one of its essential parts. In comparison with the above, all ordinary chemical work may be termed the registration of successive static states of matter. The analyst pulls to pieces, the synthetic chemist builds up; each records his work as so many atoms transferred from one condition to another, and he is satisfied to exhibit the body produced quietly resting in the bottom of a beaker motionless, static. The electrolytic cell tells us the stress of chemism for specified conditions as electromotive force; the splendid work done in thermochemistry enables us to know the whole energy involved when A unites with B, or when A B goes through any transformation however intricate, but it does not inform us of the dynamical equation which accompanies them, and which should account for the interval between the static states.

Whenever we look outside of chemistry we find that the lines of the great theories, along which progress is making, are those of dynamic hypotheses; if we go to our biological brethren we see them, too, moving with the current; the geologist studies upheavals, denudation, rate of subsidence, glacial action and all

kinds of changes in reference to their velocity; the physiologist is actively registering the time element in vital phenomena through the rate of nervous transmission, the rate of muscular contraction, the duration of optical and auditory impressions, etc.; and we cannot ignore the fact that all the great living theories of the present contain the time element as an essential part. Now, I cannot but ask whether one reason why chemistry has evolved no great dynamical theory, that the word affinity has disappeared from our books, that we go on accumulating facts in all directions but one, and fail to draw any large generalization which shall include them all, may not be just because we have made so little use of the fundamental concept, time. To expect to draw a theory of chemical phenomena from the study of electrical decompositions and of thermochemical data, or from even millions of the customary static chemical equations would be like hoping to learn the nature of gravitation by laboriously weighing every moving object on the earth's surface and recording the foot-pounds of energy given out when it fell. The simplest quantitative measure of gravity is, as every one knows, to determine it as the acceleration of a velocity; when we know the value of $g$ we are forever relieved, in the problem of falling bodies, from the necessity of weighing heterogeneous objects at the earth's surface, for they will all experience the same acceleration! May there not be something like this grand simplification to be discovered for chemical changes also?

The study of the speed of reaction has but just begun; it is a line of work surrounded with unusual difficulties, but I confidently believe it contains a rich store of promise; all other means for measuring the energies of chemism seem to have been tried except this. Is it not therefore an encouraging fact that to us, the chemists of the nineteenth century, is left for exploration the fruitful field of the true dynamics of the atom, the discovery of a time rate for the attractions due to affinity? I like to think so, and let us hope that the Newton of Chemistry may come in our day and while we yet have voices to honor him.

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# PAPERS READ.

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OPTICAL METHODS OF ESTIMATING SUGAR IN MILK. By Prof. H. W. WILEY, Agricultural Department, Washington, D. C.

[ABSTRACT.]

THE paper contains a review of the determination of specific rotary power of milk sugar and fixes this number at 52.5 $(\alpha)_D$ as the one nearest the true power. Extensive experiments are described with various reagents for precipitating the milk albumen in which it is shown that the commonly accepted method by basic lead acetate is wholly unreliable. It is further shown that perfectly reliable results can be obtained by using acid mercuric nitrate or mercuric iodide acidified with acetic acid. The paper also compares the results thus obtained with those reached by evaporating the milk to dryness and extracting sugar with aqueous alcohol. By numerous combustions with soda lime it is shown that the basic lead acetate does not remove all the albumen from milk, but that there is left in solution as much as .25 per cent of these bodies. Since they are all laevorotatory, the effect of their presence is to make the dextrorotatory power of the lactose appear too small.

Similar combustions show that while the mercury reagents do not remove all the albumen, yet they do so to such a degree as to reduce their disturbing effects to a minimum and render them negligible. The paper closes with directions, based upon the experiments given, for making optical analysis of sugar in milk which are both reliable and speedy. The complete paper is in vol. 6 No. 5, of the American Chemical Journal.

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ON CHLORPROPIOLIC ACID AND CERTAIN SUBSTITUTED ACRYLIC AND PROPIONIC ACIDS. By Prof. C. F. MABERY, Case School of Science, Cleveland, Ohio.

[ABSTRACT.]

BY treating chlorbromacrylic acid with baric hydrate under carefully regulated conditions, I find that the elements of hydrobromic

acid may be eliminated with the formation of chlorpropiolic acid. Although this acid has not yet been obtained perfectly pure, its identity is established by the formation of addition-products with hydrobromic and hydriodic acids both of which have been analyzed.

The chloriodacrylic acid thus obtained melts at 84°–85° and the chlorbromacrylic acid which is probably identical with the acid from which chlorpropiolic was prepared, at 68°–70°. In 1879 Wallack mentioned briefly the formation of chlorpropiolic acid beside dichloracrylic acid as one of the products of the decomposition of chloralid but no attempt was made to prepare its addition-products.

I have also observed that chlorine is readily absorbed by chlorbromacrylic acid and at ordinary temperatures the formation of the addition-product is complete in a few hours. The resulting bromtrichlorpropionic acid forms an oil with water and is quite soluble in carbonic disulphide from which it separates when cooled to 0° in prismatic crystals which melt at about 80°. By the action of baric hydrate in aqueous solution the elements of hydrobromic acid are removed forming trichloracrylic acid with a melting point of about 75°.

The elements of hydrobromic acid are easily eliminated from both $\alpha$ and $\beta$ dibromdichlorpropionic acids with the formation of the corresponding bromdichloracrylic acids. These acids both melt at 78°–80° and although their salts show certain differences in their water of crystallization the acids themselves have not been sufficiently studied to determine whether they are different or identical in form.

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CONTINUOUS ETHERIFICATION. By Dr. L. M. NORTON AND C. O. PRESCOTT, Mass. Institute of Technology, Boston, Mass.

SINCE the examination of the process of continuous etherification by Williamson,[1] and the explanation of it in his classical research, our knowledge of its possible applications has made no material progress. The formation of ethers by the action of sulphuric acid upon alcohols has found practical application only in the manufacture of ethyl ether in the manner proposed by Boullay[2] before the

[1] Ann. d. Chem. v. 77, 37, and v. 81, 73. [2] Jour. Phar. v. 1, 96.

course of the reaction was understood, and in the manufacture of methyl ether,[3] which is now used extensively for cooling purposes. We have re-examined the formation of ethyl ether by this process in order to fix more carefully the limits of temperature within which the reaction can be effected, and also the temperature at which etherification is most complete, and we have also investigated the behavior of propyl, isobutyl and isoamyl alcohols when subjected to the process of etherification. We have examined also the formation of mixed ethers by this process.

*Ethyl Alcohol.*

The apparatus used in all the experiments described below was essentially that originated by Boullay, and afterward used by Williamson. It consists of a two-litre flask, with a wide mouth closed by a cork through which passes a thermometer, a drop-funnel, and a delivery tube leading to a condenser cooled continually with ice water.

In the first series of experiments 200 grams of commercial 90 per cent. alcohol were subjected to etherification in each experiment. Twenty grams of alcohol were mixed with 36 grams of ordinary strong sulphuric acid, placed in the flask, which was then heated to the desired temperature in an oil-bath, and the mixture was maintained at the desired temperature while the remaining alcohol was slowly added through the drop-funnel. It is evident that if the distillate was subjected to fractional condensation and the undecomposed alcohol returned to the generating flask and only the ether collected, in sufficient time the alcohol would be changed to ether, even at a temperature far too low for advantageous etherification. As we desired to examine the amount of alcohol changed to ether at different temperatures, we allowed the ether and undecomposed alcohol to distil together from the generating flask, and subsequently subjected the distillate to fractionation. The distillates from temperatures below 160° were free from sulphurous anhydride. They were treated with solid caustic potash to remove any traces of sulphuric acid and then distilled from quick-lime. After three fractionations, the portions boiling between 35° and 45° were weighed. In these experiments 163 grams of pure ethyl alcohol were available for etherification.

[3] Tellier, Arch. Phar. v. 16, 57.

| Temperature of formation. | Weight of ether obtained. | Per cent. of theoretical yield of ether. |
|---|---|---|
| 120°–125° | 12 grams. | 7.35 per cent. |
| 125°–130° | 27 " | 16.55 " |
| 130°–135° | 45 " | 27.58 " |
| 135°–140° | 45 " | 27.58 " |
| 140°–145° | 47 " | 28.81 " |
| 145°–150° | 47 " | 28.81 " |

A second series of experiments was now made, and the distillates were fractionated with the utmost care. In these experiments 150 grams of 90 per cent. alcohol were used, and 118 grams of ethyl alcohol were available for etherification. The specific gravity of the ether obtained was 0.744 at 0° compared with water at the same temperature. This specific gravity would indicate the presence of a minute quantity of alcohol in the ether.

| Temperature of formation. | Weight of ether obtained. | Per cent. of theoretical yield of ether. |
|---|---|---|
| 115°–120° | 5 grams. | 4.2 per cent. |
| 120°–125° | 10 " | 8.4 " |
| 125°–130° | 20 " | 16.8 " |
| 130°–135° | 33 " | 27.7 " |
| 135°–140° | 43 " | 36.1 " |
| 140°–145° | 52 " | 43.6 " |
| 145°–150° | 47 " | 39.5 " |
| 150°–155° | 49 " | 41.0 " |
| 155°–160° | 48 " | 40.3 " |
| 160°–165° | ? " | |

These results would indicate that the action of alcohol upon ethylsulphuric acid begins at a temperature much lower than has been supposed, rises in rapidity and completeness until the temperature of 145° is reached, where the maximum yield of ether is obtained. Above 150° the yield begins to lessen, and doubtless the formation of ethylene begins, but the yield does not diminish greatly until 160° is reached. At 160° the formation of sulphurous anhydride begins and numerous gaseous products are evolved, and the sulphuric acid is soon destroyed, as has been observed by others.[4] Ether continues to be formed above 160° in small quantities, and, according to Mitscherlich,[5] is even found among products formed at 200° and above that temperature.

[4] Gmelin, Handbuch v. 4, 552. [5] Ann. Ch. Phys. v. 3, 7, 12

*Propyl Alcohol.*

We were unable to find any evidence that this alcohol was ever subjected to the process of continuous etherification. We took 50 grams of propyl alcohol for our experiment. Fifteen grams were mixed with 20 grams of sulphuric acid, the mixture heated at 135°, and the remaining alcohol added in the usual way. A colorless distillate was obtained, at the same time there was a slight evolution of sulphurous anhydride and a slight deposition of tar in the generating flask. The distillate was treated with solid caustic potash, then distilled from lime, and was found to boil between 80° and 90°. It was next washed with water, distilled again from lime, and then allowed to stand with sodium until all action ceased. Its boiling point was then between 82° and 84°; it possessed a strong ethereal odor, and agreed in all respects with the propyl ether described by Chancel[6] and Linneman.[7] The yield is very good, and this method will prove the most convenient for the preparation of propyl ether.

*Isobutyl Alcohol.*

It is well known[8] that at a high temperature sulphuric acid withdraws water from isobutyl alcohol and produces isobutylene. We have subjected isobutyl alcohol to the ordinary process of continuous etherification at 120° and also at 135°. In both cases sulphurous anhydride was freely evolved, and tar remained in the generator.

A yellowish distillate was obtained, which upon purification and fractionation proved to consist of undecomposed isobutyl alcohol. We were unable to obtain any appreciable quantity of isobutyl ether.

*Isoamyl Alcohol.*

We next investigated the behavior of isoamyl alcohol under the ordinary conditions of continuous etherification. At temperatures very little above 100° a violent action begins, and sulphurous anhydride is freely evolved. Before the temperature of 140° can be reached the sulphuric acid is destroyed, and only tar remains in the generator. As isoamyl ether boils at 176° it is evident that it cannot be produced by this method. Below 140° a distillate was

[6] Ann. d. Chem. v. 151, 304. [7] Linneman, Ann. d. Chem. v. 161, 37.
[8] Lermontoff, Ann. d. Chem. v. 196, 117, *et al.*

obtained, which proved to contain undecomposed isoamyl alcohol and hydrocarbons of the $C_nH_{2n}$ series. We were unable to confirm the statement of Balard[9] that small quantities of isoamyl ether are formed by the action of sulphuric acid upon isoamyl alcohol.

### *Methyl and Ethyl Alcohols.*

The authority for the statement that mixed ethers can be obtained by the process of continuous etherification rests upon two experiments of Williamson.[10] It seemed desirable to test the applicability of this process to the formation of mixed ethers anew, especially as Guthrie[11] was unable to repeat one of Williamson's experiments. We chose for an experiment a mixture of methyl and ethyl alcohols, containing 1 mol. of $CH_3OH$ to 1 mol. of $C_2H_5OH$. This mixture was treated in the usual manner at 140°, and the utmost care observed in condensing the products. A colorless distillate, free from sulphurous anhydride, was obtained, and at the same time a gas, which we were unable to condense, escaped from the apparatus. This gas possessed a strong ethereal odor, and was doubtless methyl ether, which boils at —23°. The distillate resolved itself upon fractionation into three portions, one boiling from 10°–15°, the second from 30°–40°, and a third portion consisting of undecomposed alcohols. We obtained from the portion boiling lowest a considerable quantity of a liquid boiling between 10° and 13°, possessing a strong ethereal odor, and corresponding in every respect with the methyl-ethyl ether prepared by Williamson[12] from sodium alcoholate and methyl iodide, and also by Würtz[13], by the action of a mixture of methyl iodide and ethyl iodide upon silver oxide. The portion of the distillate boiling between 30° and 40° consisted mainly of ethyl ether. The yield of the mixed ether was very good. The three possible ethers appear to be formed simultaneously, but the mixed ether is formed in much the largest proportion.

### *Ethyl and Propyl Alcohols.*

A mixture of equivalent parts of these alcohols was next treated in the usual manner. A colorless liquid was obtained, which resolved itself upon fractionation into ethyl ether, a mixture of ethyl and propyl alcohols, and a portion boiling between 60°–80°.

[9] Ann. d. Chem. et Phys. v. 3, 12, 294. [10] Ann. d. Chem. v. 81, 77.
[11] Ann. d. Chem. v. 105, 37. [12] Ann. d. Chem. v. 81, 77. [13] Ann. Ch. Phys. v. 3, 46, 222.

The portion boiling between 60° and 80° was washed with water, distilled from quick-lime, and finally treated with an excess of sodium to remove any alcohols present, and rectified. The liquid then boiled between 66° and 68°, and possessed an ethereal odor, and gave the following results upon analysis: 0.2286 gram of substance furnished 0.5620 gram of $CO_2$ and 0.2827 gram of $H_2O$.

| | Theory for $C_5H_7OC_2H_5$. | Found. |
|---|---|---|
| C | 68.17 | 67.04 |
| H | 13.64 | 13.74 |

The analysis leaves no doubt that the substance is the ethyl-propyl ether which was first prepared by Chancel[14] by the action of ethyl iodide upon propyl alcohol and caustic potash.

*Ethyl and Isobutyl Alcohols.*

Equivalent parts of these alcohols were subjected to the usual treatment. Sulphurous anhydride was freely evolved, and a yellow distillate with a very disagreeable odor obtained. The distillate consisted almost entirely of undecomposed alcohols and no ether could be obtained from it. The mixture behaved exactly as did the isobutyl alcohol alone.

*Methyl and Isoamyl Alcohols.*

Methylisoamyl ether was prepared by Williamson[15] by the continuous etherification of a mixture of these alcohols. We repeated his experiments, following his directions with the utmost exactness. Sulphurous anhydride was evolved in large quantities. In the distillate obtained we found undecomposed alcohols and products similar to those obtained from isoamyl alcohol alone under like conditions, but were unable to detect the presence of methyl-isoamyl ether. We made repeated attempts at 135° and 140°, but the distillate in every case consisted almost entirely of the alcohols which had distilled undecomposed as soon as the sulphuric acid had been all reduced. An attempt by Guthrie[16] to obtain ethyl-isoamyl ether by continuous etherification, in the manner described by Williamson, gave similar results, and Guthrie was unable to obtain the ether by this method. As our experiments show that etherification does not take place to any extent, certainly in the

[14]Zeit. f. Chem. 1869, 367. [15]Ann. d. Chem. v. 81, 77. [16]Ann. d. Chem. v. 105, 37.

case of ethyl alcohol, below 105°, and as isoamyl alcohol decomposed sulphuric acid with the evolution of sulphurous anhydride at that temperature, it is evident that the ordinary process of continuous etherification can only be applied to the formation of the simple and mixed ethers from the simplest alcohols, and it is not probable that it can be used satisfactorily for the etherification of alcohols containing more than three atoms of carbon.

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ANTHRACENE FROM WATER-GAS TAR. By ARTHUR H. ELLIOTT, School of Mines, Columbia College, New York, N. Y.

[ABSTRACT.]

THIS paper treats of the determination of anthracene in various samples of water-gas tar as obtained from gas-works using this so-called water-gas process. The tar is obtained in that part of the process where the mixture of carbonic oxide and hydrogen containing the vapor of petroleum naphtha is passed through red hot retorts, and the members of the paraffine series of hydrocarbons become, under the influence of the heat, converted into a mixture of ethylene, acetylene and members of the aromatic series.

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ON THE CHEMISTRY OF FISH. By Prof. W. O. ATWATER, Wesleyan University, Middletown, Conn.

[ABSTRACT.]

THIS paper gives a brief account of the progress of an investigation of the chemical composition and nutritive values of American food-fishes and invertebrates, which is being conducted in the laboratory of Wesleyan University under the auspices of the Smithsonian Institution and the United States Fish Commission, and of which brief accounts were presented at the Boston and Cincinnati meetings of the Association.

In its present status the investigation includes:

1. Chemical analyses of:

| | | | |
|---|---|---|---|
| *a* Flesh of fish, | 118 | specimens belonging to | 51 species. |
| *b* " " invertebrates, | 64 | " " | 11 " |
| Total, | 182 | " " | 62 " |

2. Experiments upon the digestibility of the flesh of fish.

3. Studies of the chemical constitution of the muscular tissues of fish.

A PRELIMINARY REPORT ON THE COMPOSITION OF THE COALS OF KANSAS. By Prof. E. H. S. BAILEY, State University, Lawrence, Kansas.

[ABSTRACT.]

THE coal-measures that underlie the eastern portion of Kansas are more extensively worked than ever before. The inclination of the strata towards the N. W. carries the beds deeper from the surface as we advance in this direction. Veins 3½ ft. in thickness are found in the extreme S. E. while those worked in the Osage region are often only 15 in. thick. Without giving details as to the occurrence of the coals, an examination of the composition of samples from the principal localities has given the following results:—

| Name. | Cherokee. | Pittsburg. | Ft. Scott. | Osage Co. | Burlingame. | Scranton. | Leavenworth. | Warren Co., Mo. | Elk Co. Pa. |
|---|---|---|---|---|---|---|---|---|---|
| Moisture. | 3 56 | 3 10 | 5 90 | 13 05 | 12 31 | 11 58 | 8 36 | 6 75 | 1 70 |
| Vol. and Combust. | 35 58 | 35 88 | 28 20 | 37 58 | 39 65 | 36 44 | 36 94 | 36 40 | 36 82 |
| Fixed carbon. | 55 04 | 55 65 | 54 10 | 38 88 | 39 79 | 42 46 | 45 67 | 45 75 | 56 50 |
| Ash. | 5 82 | 5 37 | 12 05 | 10 49 | 8 25 | 9 52 | 9 03 | 11 10 | 3 61 |
| Total. | 100 00 | 100 00 | — | 100 00 | 100 00 | 100 00 | 100 00 | 100 00 | 98 63 |
| Sulphur. | 3 91 | 2 82 | — | 3 26 | 5 24 | 2 74 | 4 46 | 2 23 | 1 36 |
| C. / Vol. and Comb. | 1 54 | 1 55 | 1 93 | 1 02 | 1 00 | 1 16 | 1 12 | 1 26 | 1 53 |

If the moisture and impurities are eliminated and the per cent of heat-producing constituents only is considered, calculating the per cent, and dividing C by volume and combustible matter gives the lower line of figures. This gives a better opportunity to compare the different coals. It will be noticed that the S. E. coals, viz., Cherokee, Pittsburg, and Ft. Scott, properly belong to one class, while those occurring in later strata, as Osage Co., etc., belong to another. The latter contain more volume and combustible matter in proportion to fixed carbon as would be expected of later coals and those more closely related to true lignites.

FERMENTATION WITHOUT COMBINED NITROGEN. By Dr. ALFRED SPRINGER, Cincinnati, Ohio.

[ABSTRACT.]

BEFORE entering into detail concerning the results attained in my experiments in this direction, I wish to make a few remarks on the great liability to error, to which the experimentalist is exposed at every step owing to the extreme minuteness of the ferments in question.

A good $\frac{1}{10}$ objective with a high eye-piece shows the ferments as colorless rods, $\frac{1}{8}$ of an inch in length and about $\frac{1}{64}$ in width, very difficult to distinguish from the fluid in which they are immersed. Again unless many are under the field of vision, it is almost impossible to determine whether they possess motion independent of the Brownian movement. Although there may be thousands present in one drop of fluid, yet their mass is infinitely small compared to it, therefore an analysis of the fluid can be but a poor criterion of their composition.

About two years ago, while experimenting with infusions of the roots of plants in water, I discovered a ferment which possessed the power of dissociating the nitrates of the soil. I noticed a copious evolution of nitric oxide proceed from roots rich in nitrates. It immediately struck me, that this arose from the action of small organisms which covered the roots of plants.

Starting out with this idea, I made separate infusions of the roots, stems and leaves of tobacco, dividing each set into four parts. Fermentation was excited in the first by the addition of small quantities of yeast, in the second by urine, in the third by the so-called spontaneous method, and in the last by the newly discovered ferment. Not only were the nitrates originally present completely dissociated, but also considerable quantities of freshly added nitrates underwent the same process. All the infusions contained amongst other ferments one special kind, noticeable by its extreme activity. In appearance it closely resembles the butyric ferment, being composed of small cylindrical rods rounded at the extremities, generally isolated, or, when joined, two by two, acting as one body. They move rapidly with a wriggling motion and often bend their bodies until they form a perfect circle.

While continuing my researches on the functions of this ferment, it occurred to me that owing to their ejecting the nitrogen they might possibly make use of only a very limited supply thereof. In

order to prove this I added the nitrogen in the form of potassium nitrate and ammonium carbonate.

Eight flasks with starch in solution and traces of potassium phosphate and magnesium sulphate were sowed with an imponderable trace of the ferment. To four, potassium nitrate, and to the other four ammonium carbonate, was added in decreasing quantities. Calcium carbonate was then added to counteract too great acidity. All the flasks containing variable quantities of potassium nitrate fermented in the same length of time, and sooner than those containing the nitrogen in form of ammonium carbonate; these also ferment independent of the amount of ammonium carbonate present.

The next step taken was to exclude nitrogenous constituents from the next four flasks. To my surprise fermentation set in six days after a trace of the ferment was added. Thinking that starch might contain some gluten, I then took some pure white rock-candy, recrystallized it from alcohol three times, added potassium phosphate, magnesium sulphate and calcium carbonate; sowed the ferment therein and in each case an active fermentation set in, resulting in the formation of butyric acid.

The utmost care was taken in all these experiments, the flasks carefully stopped with cotton so that nothing but filtered air could pass into them. These experiments differ so materially from anything ever before observed that I cannot do otherwise than state the bearings they must have on the study of fermentation and life itself. Provided there was no error and I feel almost certain there was not, the ferments could do only one of two things, either abstract nitrogen from the air, or use no nitrogen at all. The first of these cases seems improbable for the following reasons: nitrogen has very little affinity for the other elements entering into the composition of life; if nitrogen were abstracted from the air the ferments would be apt to remain on the surface of the fluid, to which the air would have access; but this is not the case, for the ferments are found in all parts of the fluid. Lastly, three combustion analyses and staining fluids under the microscope showed no trace of albuminoid matter. The combustion analyses were made two weeks after the sowing of the ferments and the objection might be made that not enough ferments had yet developed to show the presence of nitrogen. At any rate I will make some more analyses when six weeks have elapsed.

The second reason which might be attributed to fermentation without combined nitrogen is as before observed, that the ferments assimilate none: yet they propagate, they convert sugar into butyric acid. Generations succeed generations and each ferment when examined under the microscope shows independent motion. But fermentation and motion without nitrogen is life without nitrogen, life without albumin, life without protoplasm; "the physical basis of life."

Should these results be verified by further investigations, protoplasm can no longer occupy the position thus far given it and there must be lower forms of motion and life than heretofore recognized.

The ferments closely resemble the nitrate ferments but are much less active. They wriggle along very slowly either isolated or two by two.

I have not yet had the time to examine the influences of many chemical reagents on them. Iodine and nitric acid do not affect them for some time. Chloroform kills them immediately.

I give these remarks as the result of the preliminary work on a series of experiments I am making now in my laboratory in connection with them.

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## EXAMINATION OF METHODS PROPOSED FOR RENDERING THE LIGHTER PETROLEUM OILS INEXPLOSIVE. By Prof. CHAS. E. MUNROE, U. S. Naval Academy, Annapolis, Md.

[ABSTRACT.]

IT having been seriously suggested that alum, sal ammoniac and camphor could be used to render the lighter petroleum oils inexplosive and it having been found in practice that camphor did diminish very markedly the readiness with which explosive gelatine or gum dynamite could be exploded the author has tested the effect of the above bodies by determining their solubility in benzoline; the flashing points of benzoline and commercial kerosene when treated with these bodies and when in their original state, and also the readiness with which, mixtures of the oils, in the two conditions, with air could be exploded. The results

showed that alum and sal ammoniac were practically insoluble in the oils and produced no effect upon them: that the camphor was soluble, 1 gram of benzoline dissolving about 1.5 gram of camphor, that an equal weight of camphor raised the flashing point of a kerosene 12°, but that on the other hand the vapor of this camphorated kerosene when mixed with air exploded with greater readiness than the original kerosene.

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THE CHEMISTRY OF THE ROLLER MILLING PROCESS. By CLIFFORD RICHARDSON, U. S. Agricultural Department, Washington, D.C.

[ABSTRACT.]

THE modern method of milling by means of rolls has been productive of such radical changes in the business of flour manufacture and the number of products, intermediary products and bye products are so numerous that it is of interest, in following the wheat through the various steps, to study the chemical composition of the material resulting from all of the processes to which the grain is subjected.

The specimens upon which the following experiments have been made are from one of the largest mills in Minneapolis, Minn., and are the result of milling Minnesota "Hard Spring Wheat."

As the wheat enters the mill it is of course contaminated with foreign seeds and dirt which are removed by appropriate machinery. It is then put through a run of stones which are set sufficiently far apart to remove only the fuzz from the end of the berry and a small portion of the outer coats. A brush machine then thoroughly cleans the wheat and leaves it ready for gradual reduction by the rolls or breaks. These consist of corrugated rolls of various forms revolving at different rates of speed thus enabling one roll to tear apart the grain which is held by the projections of the other. The products of these several breaks go to separators or scalping reels where the fine material or chop is removed and the coarser particles go on to the next break finally emerging from the last as bran.

The chops by means of purifiers and bolts are freed from the branny portions and fine flour and the middlings graded into several

classes which go to smooth rolls for reduction to flour or in part to a run of stones. The resulting flours are graded according to their quality by various bolts and the bye products of all these processes are collected as shorts and the various kinds of tailings, dust and low grade flours all of which appear in the representative samples which have been analyzed.

One of the peculiar advantages of the process is the removal in the first few boltings after the use of the scalping reels of the greater part of the gum of the grain which when passed through smooth rolls with the tailings are easily flattened and separated by appropriate bolting machinery, thus making it possible to produce a flour uncolored by the oily and nitrogenous matters of the gum.

The results which have been obtained in the analyses of the specimens referred to are presented in the accompanying tables.

They show that the soft interior of the grain which is removed in the first breaks is of a starchy nature, the albuminoids and gluten increasing toward the exterior of the grain. The outer portions also contain more oil and ash and consequently more phosphates.

While the gluten is more abundant in the outer portion of the grain and especially in the part adherent to the bran which is removed in the last break there is none at all in the outer coatings themselves, the so called gluten cells of the embryonal membrane containing similar substances to the embryo or gum of which it is a continuation. All of the gluten of the wheat is in the endosperm or floury portion of the berry and can be more completely recovered and carried into the various grades of flour by the roller process at least with Hard Spring Wheats than by other methods of milling.

The shorts removed by the bolting and aspirating machines are, like the bran, rich in albuminoids, oil and ash but not as much so in the two latter constituents.

The graded middlings both uncleaned and cleaned show very regular variations in the various constituents, ash, fat and fibre decreasing from what is known as No. 1 to No. 5 and the albuminoids or gluten being the best in No. 4.

The effect of cleaning is to increase the percentage of gluten while not altering the percentage of nitrogen showing that the material removed by the process is not rich in gluten.

The flour, produced by the reduction of the purified middlings is not as rich in gluten, ash or fibre as the middlings themselves. The cause of this is not quite apparent as the tailings with one exception are not rich in gluten; in fact, in two cases contain none and in a third less than one per cent.

The tailings from the middlings purifiers in a like manner contain no gluten in the No. 1 purifier and gradually increase till those from No. 6 are rich.

The different flours are mixed for the market in the three grades Bakers', Patent and Low Grade. The Patent is of course the highest grade and whitest. It contains however less gluten than the bakers' grade and the least ash, oil and fibre of any. The low grade flour is very rich in nitrogen but extremely poor in gluten, the result of mechanical and chemical causes which have injured the flour in the process of manufacture.

The remaining analyses are of technical interest. Among them are those of the gums extracted at different points in the purification of the tailings. That known as "second gum" seems to be freer from impurities and has been analyzed in detail showing that one-third of the substance is albuminoids, over fifteen per cent oil, and nearly nineteen per cent a sugar-like substance making it of considerable interest.

I shall consider the results more at length in a report to be issued by the Department of Agriculture, Washington, D. C.

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ANALYSIS OF A MURAL EFFLORESCENCE. By Prof. CHAS. E. MUNROE, U. S. Naval Academy, Annapolis, Md.

THE incrustations which so frequently disfigure our finest brick buildings have sometime since received attention from chemists and engineers, but we find marked differences in the statements made as to their composition. Thus, according to [1]Trantwine, [2]Pemberton, and [3]Goldsmith they consist largely of magnesium sulphate and it is suggested that they are formed either through

[1]Jour. Frank. Inst. [3] LXXV, 259,1878. [2]Jour. Frank. Inst. [3] LXXVI, 52,1878.
[3]Proc. Phil. Acad. Sci. XXVIII, 334,1876.

the action of the sulphuric acid in our city atmospheres on the magnesium salts in the mortar, or through the action of this acid, from the coal used in burning the bricks, on the clay from which the bricks are formed. [4]Watts and [5]Gillmore, on the other hand, find the efflorescences to consist principally of sodium carbonate with some sodium or magnesium sulphates.

In 1876 a somewhat costly building was erected here in which considerable elaborateness of design was displayed, but, before six months had passed an efflorescence appeared upon it and to such an extent as to almost completely destroy the artistic effect, and in spite of the many severe storms to which it has been exposed and notwithstanding the fact that it is, as my tests have showed, completely soluble in water, it yet exists in apparently undiminished quantity.

The building was constructed of wood-burned, pressed brick, made from Washington clay, for the outside courses, and these were laid in mortar made with lime from Texas, Pa., and pointed with black mortar. The interior wall was of common brick and the space between was filled with Rosendale or Round Top cement mixed with Texas lime mortar in the proportion of one of cement to two of mortar. During the process of building and after completion the structure was pretty well soaked by rains. The town contains less than 7,000 inhabitants and there are no manufacturing establishments whatever, so that the air is quite pure save for the solids taken up from the salt water of the contiguous bay and river. These efflorescences are rare here and are confined wholly to buildings erected in recent years and usually to those made from pressed bricks.

As has been said, this efflorescence was found to be readily soluble in cold water with the exception of 2.62 per cent of residue, which proved to be particles of brick dust. Leaving this out of account the analysis gave

| | |
|---|---|
| Sodium carbonate | 61.67 |
| Sodium sulphate | 34.33 |
| Sodium chloride | 1.09 |
| Water | 2.96 |
| | 100.05 |

[4] Dict. Chem., I, 792. [5]Limes, Mortars and Cements, 294, 1863.

A STUDY OF THE PHENOMENON OF DELIQUESCENCE. By Prof. CHAS. E. MUNROE, U. S. Naval Academy, Annapolis, Md.

IN the Proc. U. S. Naval Institute 9, 332, 1883, I have given the results of an observation on the comparative attractive power of calcium chloride and bleaching powder for moisture when exposed to a moist atmosphere. Having allowed these substances to remain exposed to this atmosphere during a very long period of time after the weights, cited there, were recorded, I was surprised to find that the increase in weight for the $Ca\,Cl_2$ was greatly in excess of that which Brandes[1] found in his experiments on the deliquescence of this substance. As, for the requirements of this experiment, the commercial salt had been used, I determined to repeat the experiment with another specimen of the salt which I had prepared.

The salt was made, according to Fresenius[2], by dissolving marble in common HCl diluted with five volumes of water. To this a thin paste of lime was added, with stirring, until it was in excess, and the mixture stood for twenty-four hours. It was then filtered; washed hydrogen sulphide was passed through it to saturation; again allowed to stand over night; and again filtered. It was then strongly acidified with pure concentrated HCl; concentrated in a porcelain dish and again filtered; then it was evaporated to dryness, a little HCl being added towards the close of the process. The residue was finally exposed to a tolerably strong heat, on the sand bath, until it was changed to a white, porous, opaque mass. This residue, when cold, was free from alkaline reaction and gave a slight reaction for water by the closed tube test. When dissolved in water and acidified it gave a faint effervescence due to carbon dioxide. Besides these substances only calcium and chlorine were found to be present. The quantitative determinations for chlorine and calcium yielded the following results.

| Wt. taken. | Wt. Ag Cl found. | of Cl found. | Theory for $Ca\,Cl_2$. |
|---|---|---|---|
| .4269 | 1.0563 | 61.16 | 63.96 |
| .5740 | 1.4164 | 61.02 | |
| Wt. taken. | Wt. Ca O found. | of Ca found. | Theory for $Ca\,Cl_2$. |
| .5113 | .2499 | 34.92 | 36.04 |

Assuming the excess of Ca present, over that necessary to form $Ca\,Cl_2$ with the Cl found to be combined with carbon dioxide, and

[1] *Schweiges Jour.*, 51, 433. [2] *Quan. Anal.* (*Am. bd.*,) 127, 1882.

taking the water by difference, we may regard the salt as having the following composition

| | |
|---|---|
| $CaCl_2$ | 97.49 |
| $CaCO_3$ | 1.28 |
| $H_2O$ | 3.23 |
| | 100.00 |

Fresenius states that the salt, made by the method described, has the composition $CaCl_2(H_2O)_2$.

The portions of salt used in these experiments were all taken from the same weighing tube and to check any error which might arise from particles of the salt becoming attached to the outside of the tube or cork, the tube was allowed to remain in the balance case for some time after each weighing made for the purpose of analysis, and the change in weight observed. The greatest change observed was a gain of .0003 grams between the weighing out of the second portion for the determination of the chlorine and that for the determination of the calcium. This would make the $CaCO_3$ as calculated a little too small but would not affect the $CaCl_2$.

The experiments for deliquescence were made by weighing out a portion of the salt in a small watch glass and placing it on a vessel containing distilled water. The top of the vessel was covered with wire gauze and the watch glasses rested upon a plate of glass placed upon this. The vessel was placed on a plate of glass beside the balance and the whole covered with a low bell glass. For each observation the bell glass was removed twice, and the weighings were made in a different atmosphere from that existing in the bell glass, but all was done as rapidly as possible and the weights were always taken in the same order. The weights of the substances taken were:

| | I. | II. |
|---|---|---|
| Wt. watch glass + salt | 1.5137 | 2.1759 |
| " " " | 1.4937 | 2 1520 |
| " " | .0200 | .0239 |

The portions taken were weighed out at 1.15 P. M., Mar. 15, and by 4.30 P. M. on the same day they had both become completely liquefied, while the liquid was perfectly transparent. On Mar. 24 a slight cloudiness appeared and persisted, without increasing in quantity or extent, to the end of the experiments. This film appeared as a plane with its edge in the surface of the liquid, and it appeared either normal to or parallel with the line of sight as

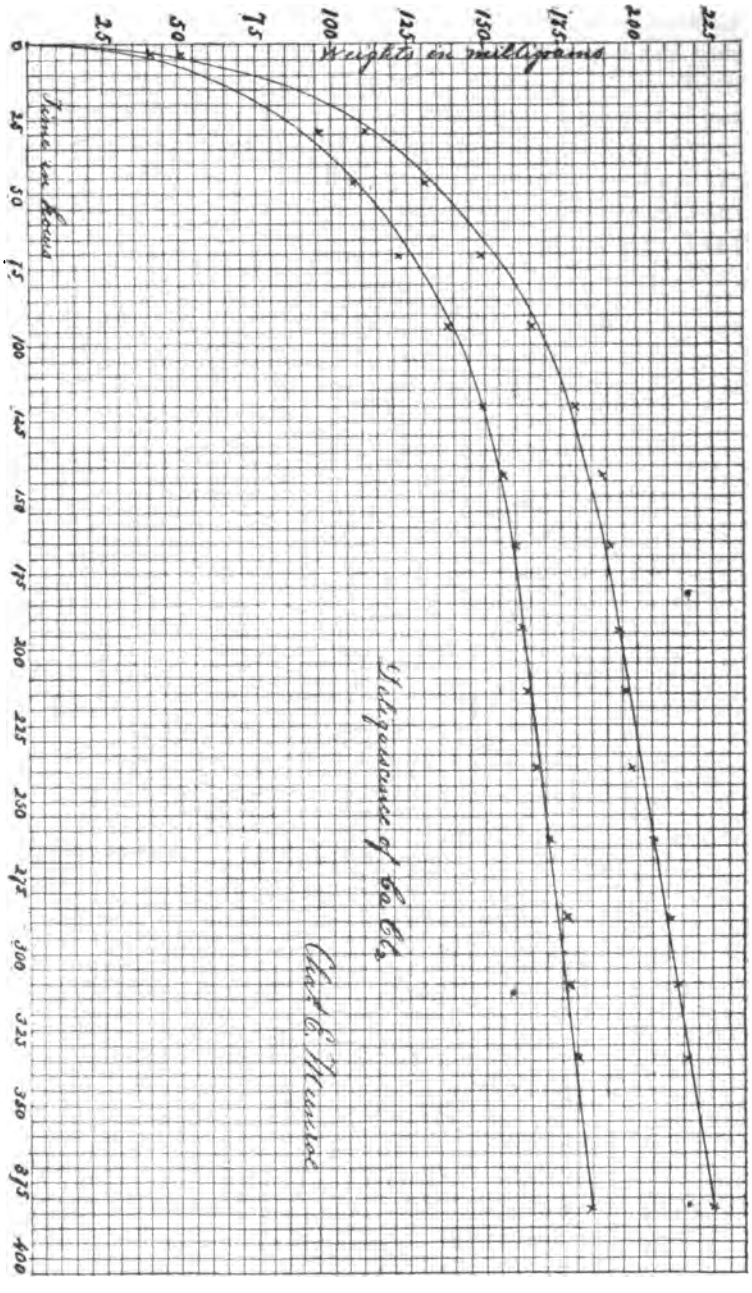
the watch glass was revolved about its major axis. After the weighings were given up, the liquid was treated with a few drops of HCl and the result was a slight effervescence and the disappearance of the film. Table I shows the results obtained up to the point of maximum increase in weight. The centigrade thermometer read was beside the balance. The English barometer, with brass scale, was in another building and I have compiled the readings from the record kept by others.

TABLE I.

| | | | | I. | | | II. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date. | Time. | A. | B. | C. | D. | E. | C'. | D'. | E'. | Thermometer. | Barometer. | Thermometer attached. |
| Mar. 15 | 1.15 P.M. | | | 1.5137 | | | 2.1759 | | | 15°.5 | 30.05 | 68° |
| " " | 4.30 " " | 3.15 | 3.15 | 1.5550 | 0.0413 | 0.0413 | 2.2270 | 0.0511 | 0.0511 | 15°.5 | 30.05 | 68° |
| " 16 | 5.25 " " | 25 | 28.15 | 1.6100 | 0.0550 | 0.0963 | 2.2937 | 0.0667 | 0.1178 | 14° | 30.30 | 68° |
| " 17 | 10.45 A.M. | 18.20 | 46.35 | 1.6220 | 0.0120 | 0.1083 | 2.3085 | 0.0148 | 0.1326 | 12°.5 | 30.28 | 67° |
| " 18 | 11.05 " " | 24.20 | 70.55 | 1.6368 | 0.0148 | 0.1231 | 2.3245 | 0.0160 | 0.1486 | 13°.5 | 30.33 | 69° |
| " 19 | 11 " " | 24 | 94.55 | 1.6515 | 0.0147 | 0.1378 | 2.3422 | 0.0177 | 0.1663 | 13°.5 | 30 | 69° |
| " 20 | 12.45 " " | 25.45 | 120.40 | 1.6626 | 0.0111 | 0.1489 | 2.3557 | 0.0135 | 0.1798 | 18°.5 | 29.7( | 65° |
| " 21 | 10.45 " " | 22 | 142.40 | 1.6698 | 0.0072 | 0.1561 | 2.3641 | 0.0084 | 0.1882 | 16°.5 | 30.25 | 66° |
| " 22 | 10.45 " " | 24 | 166.40 | 1.6740 | 0.0042 | 0.1603 | 2.3681 | 0.0040 | 0.1922 | 19° | 30.31 | 61° |
| " 23 | 18.40 P.M. | 27 | 193.40 | 1.6763 | 0.0023 | 0.1626 | 2.3702 | 0.0021 | 0.1943 | 15°.5 | 30.03 | 68° |
| " 24 | 10.55 A.M. | 21.15 | 214.55 | 1.6777 | 0.0014 | 0.1640 | 2.3720 | 0.0018 | 0.1961 | 15° | 29.81 | 69° |
| " 25 | 11.15 " " | 24.20 | 239.15 | 1.6803 | 0.0026 | 0.1666 | 2.3740 | 0.0040 | 0.1981 | 18°.5 | 30.07 | 68° |
| " 26 | 11 " " | 23.45 | 263.00 | 1.6854 | 0.0051 | 0.1717 | 2.3819 | 0.0079 | 0.2060 | 19°.5 | 29.59 | 62° |
| " 27 | 11.45 " " | 24.45 | 287.45 | 1.6907 | 0.0053 | 0.1770 | 2.3871 | 0.0052 | 0.2112 | 18°.5 | 29.7[illegible] | 64° |
| " 28 | 10.45 " " | 23 | 310.45 | 1.6914 | 0.0007 | 0.1777 | 2.3892 | 0.0021 | 0.2133 | 18°.5 | 29.8[illegible] | 67° |
| " 29 | 10 " " | 23.15 | 334.00 | 1.6940 | 0.0026 | 0.1803 | 2.3917 | 0.0025 | 0.2158 | 25°.5 | 29.6[illegible] | 68° |
| " 31 | 11 " " | 49 | 383.00 | 1.7036 | 0.0096 | 0.1899 | 2.4010 | 0.0093 | 0.2251 | 12°.5 | 30.1[illegible] | 75° |

A gives the time in hours between each observation.
B " " " " " from the first "
C and C' give the weight observed.
D and D' " " increase of weight for each observation.
E and E' " " " " " from each observation.

The following chart shows graphically the rate of absorption of moisture, the abscissæ representing the time in hours (column B) and the ordinates the weight in milligrams (columns E and E').


Weights in milligrams
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
Scale for Acetic
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
Solid pressure of CO2 CO2
Class C. Measure

An inspection of these results shows that while the absorption goes on continually until it attains a maximum yet the amount absorbed in unit of time seems to vary with the temperature and pressure and it is probable that if these remain constant we shall obtain a more nearly uniformly decreasing rate. In his "Examination of Substances by the Time Method," Hannay has observed the rate at which the moisture was given off when Ca $Cl_2$ 6 $H_2O$ was dried in air at 100°, and, on comparing his Curve VI opposite page 385[3], we shall note a singular resemblance to the curve given here notwithstanding that the observations were made from quite opposite standpoints.

It is to be regretted that the maximum increase of weight in my experiments should have been attained as the temperature fell and the barometer rose markedly, for these conditions might give rise to a deposition of moisture from the atmosphere in the bell glass which was presumably saturated. However, no bedewing was observed even after close inspection of the bell and watch glasses, yet this opinion is strengthened by the fact that while during the subsequent four days the temperature remained nearly constant at 16°, yet the average weight for I was 1.6968 and for II 2.3922 grams. After this the weighings were continued for some time but they fluctuated apparently, though not always, with the temperature, until when the temperature rose to 28°.5 the weights were 1.6573 grams for I, and 2.3397 grams for II. This variation in the power of bodies to attract or hold water at moderate temperatures, owing to a change of temperatures has been pointed out in the case of lime and ethyl alcohol by Squibb[4], and Roscoe[5] found in studying the hydrates of the volatile acids that under given circumstances of temperature and pressure there is for each acid a certain proportion of water which forms a stable compound, a weaker acid under that temperature and pressure giving off water, and a stronger acid giving off acid until the most stable compound remains behind.

In order to determine whether moisture was deposited on the vessel, an empty watch glass, nearly similar in form and size to those used, was placed beside them under the bell and weighed with the results shown in Table II.

[3] "Jour. Chem. Soc.," XXXII, 1877. [4] Squibbs Ephemeris, II, 533, 1884.
[5] Quar. Jour. Chem. Soc. XIII, 146.

TABLE II.

| DATE. | WEIGHT. | TEM. | BAR. | TEM. | DATE. | WEIGHT. | TEM. | BAR. | TEM. |
|---|---|---|---|---|---|---|---|---|---|
| Apr. 25 | 2.0699 | 19°.5 | 29.76 | 65° | May 13 | 2.0699 | 19° | 29.93 | 69° |
| 26 | 2.0698 | 18°.5 | 29.77 | 68° | 14 | 2.0698 | 19° | 29.90 | 67° |
| 27 | 2.0698 | 18°.5 | 30.10 | 68° | 15 | 2.0696 | 19° | 29.93 | 68° |
| 28 | 2.0698 | 19°.5 | 30.06 | 68° | 16 | 2.0699 | 19°.5 | 29.75 | 68° |
| 29 | 2.0698 | 20°.5 | 30.02 | 72° | 17 | 2.0697 | 19°.5 | 29.91 | 67° |
| 30 | 2.0700 | 20° | 30.30 | 65° | 19 | 2.0699 | 20°.5 | 29.97 | 69° |
| May 1 | 2.0699 | 21°.5 | 30.03 | 68° | 22 | 2.0697 | 23°.5 | 30.20 | 76° |
| 2 | 2.0699 | 22°.5 | 29.88 | 76° | 27 | 2.0700 | 21°.5 | 29.86 | 71° |
| 3 | 2.0699 | 22° | 30.32 | 69° | 31 | 2.0697 | 17° | 30.19 | 67° |
| 4 | 2.0699+ | 21° | 30.22 | 69° | June 4 | 2.0699 | 23° | 30.05 | 81° |
| 5 | 2.0698 | 20°.5 | 30.02 | 76° | 8 | 2.0699 | 24° | 29.75 | 74° |
| 6 | 2.0699 | 21°.5 | 29.84 | 70° | 11 | 2.0696 | 24°.5 | | |
| 7 | 2.0699 | 21° | 29.86 | 66° | 18 | 2.0698 | 24°.5 | | |
| 8 | 2.0698 | 19°.5 | 29.90 | 70° | 21 | 2.0699 | 28°.5 | | |
| 9 | 2.0697+ | 20°.5 | 29.92 | 69° | 25 | 2.0699 | 28°.5 | | |
| 10 | 2.0699+ | 20° | 29.77 | 70° | July 8 | 2.0701 | 24° | | |
| 11 | 2.0699+ | 20°.5 | 29.69 | 71° | Aug. 18 | 2.0701 | | | |
| 12 | 2.0699+ | 18°.5 | 30.01 | 68° | | | | | |

Mean 2.06985+ Maximum 2.0701 Minimum 2.0696

Although there was no such marked difference in temperature and pressure as occurred during March 29 to 31, yet during May 27 to 31 there was a similar change. These results show also the uniformity in the action of the balance at all the observed temperatures.

Let us now take the weights obtained from April 1 to April 4 as representing the maximum increase of weight at 16° and we have the following

TABLE III.

| Experiment. | Wt. Substance taken. | Maximum wt. for 16°. | Total gain in wt. ab. 16°. | Wt. $CaCl_2$ in Substance taken. | Wt. gained for 100 parts of $CaCl_2$ | Molecules of $H_2O$ attracted by one molecule of $CaCl_2$. | |
|---|---|---|---|---|---|---|---|
| I | .0200 | .1831 | .1631 | .0191 | 853.9 | 52.6 | |
| II | .0239 | .2163 | .1924 | .0228 | 843.9 | 52.04 | |

Brandes found that 100 parts of his salt attracted 124 parts of water, after an exposure of 96 days, and from this we find that one molecule of the salt attracted 7.64 molecules of water. Hence my result is about seven times greater than that obtained by Brandes. The attraction too is found to be greater than that existing in the cryohydrate discovered by Guthrie.

The observations here recorded are only preliminary and it is recognized that the method employed is subject to several sources of error. To correct these it is proposed to arrange the experiments so as to maintain a nearly constant temperature. As the time required in the method used is very long it is proposed to shorten it by adding to the weighed portion of the anhydrous salt a determined quantity of water, but less than the amount which the salt would attract at the temperature of the experiment, and then to determine the rate of absorption from that point to the point of complete saturation. We may at least by this means determine the total attracting power at a given temperature with celerity and precision.

It is proposed too to use a vessel having the form of a right cylinder and of a sufficiently large diameter to render the effect of capillarity very slight, for as the absorption takes place from the surface, this is the only form of vessel in which the area of exposed surface will remain constant with a change in the volume of the liquid.

Finally it is proposed to use a substance which is deliquescent but which can withstand a high temperature for a considerable time without undergoing any other change in its constitution than loss of water, for in no other way can we have satisfactory evidence of complete dehydration.

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AN EXPLANATION OF GLADSTONE AND TRIBE'S "2—3 LAW IN CHEMICAL DYNAMICS." By Prof. JOHN W. LANGLEY, University of Michigan, Ann Arbor, Mich.

IN the proceedings of the Royal Society Vol. XIX, page 498, and also in the Quarterly Journal of the Chemical Society, Vol. 9, will be found a paper by Messrs. Gladstone and Tribe entitled "A Law in Chemical Dynamics." The authors show, by a record of ex-

periments, that if a plate of metal is suspended in a solution of another metal which it can precipitate (the plate being hung so that it reaches neither to the top nor the bottom of the liquid), the rate of chemical action shown by the loss of weight in the suspended plate, for a given period of immersion, will vary with

ROTATION, BRUSH AND CENTRIFUGAL EXPERIMENTS.

The numbers given are for 1 cm.² of acting surface and for 1 minute of time, in fractions of a milligramme.

| | Rotation. | | Brush. | | Gravity. | | Centrifugal. | |
|---|---|---|---|---|---|---|---|---|
| Per cent. of Ag. $NO_3$ | Actual Weights. | Weights divided by % | Actual Weights. | Weights divided by % | Actual Weights. | Weights divided by % | Actual Weights. | Weight divided by % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| .075 | .087 | 1.16 | | | | | | |
| .15 | .185 | 1.2 | | | .00375 | .025 | .089 | .59 |
| .225 | .315 | Av. 1.48 { 1.4 | | | | | .139 | .61 |
| .30 | .475 | 1.58 | | | .0125 | .041 | .215 | .71 |
| .375 | .555 | 1.48 } | | | | | | |
| .45 | .630 | 1.40 | | | .0217 | .048 | .337 | .74 |
| .60 | .925 | 1.55 } | | | .0337 | .056 | .484 | .80 |
| .90 | | | | | .0646 | .072 | .732 | .82 |
| 1.20 | | | | | | | 1.084 | .90 |
| .1 | | | .018 | .18 | | | | |
| .2 | | | .074 | .37 | | | | |
| .4 | | | .270 | .67 | | | | |
| .6 | | | .337 | .56 | | | | |
| .8 | | | .411 | Av. .60. { .51 | | | | |
| 1.0 | | | .537 | .54 | | | | |
| 1.2 | | | .722 | .60 | | | | |
| 1.6 | | | 1.070 | .67 | | | | |
| 2.4 | | | 1.600 | .66 } | | | | |

*Law.* Per cents of silver in powers of 2. Copper dissolved will be in the corresponding powers of 2.25.

the percentage strength of the solution of the salt in a remarkable manner; which they epitomize in the statement, that if the percentages of salt be expressed by a series of the powers of 2, the chemical action will be expressed by the corresponding powers of 3, so that for percentages represented by 1, 2, 4, 8, etc., the rate

of action will be 1, 3, 9, 27, etc. They further state that this law of action holds good up to about three per cent., and that for solutions weaker than this, they have demonstrated it through a range of from 1 to 1,000,000.

They also give for the law a mathematical expression which seems to have been defectively printed, for when the typographical errors are corrected I find it to be expressed by

$$\log. C = \log. p. \times \frac{\log 3}{\log 2} + \log. K$$

where C is the rate of chemical action, p is the proportionate quantity of salt, and K is a constant. In the particular example given in their article they employed a plate of copper suspended in a solution of argentic nitrate. But the authors do not give any explanation of the law which they have discovered.

The following question at once arises, Is the rate of metallic precipitation for varying strengths of the solution due to the action of chemism alone, or, is the operation of chemical affinity compounded with one or more purely physical forces? and if so, what is the relative part contributed by each?

Messrs. Gladstone and Tribe point out that there are two currents, or mass movements produced. One, a light blue ascending stream of a dilute solution of silver and copper nitrates; the other, a deep blue descending current of copper nitrate containing about three times as much $NO_3$ as the main solution. Obviously the first step in an investigation of their results should be to bring the fluid against the plate with a uniform velocity. To accomplish this a piece of copper was slightly curved and fastened to an arm which carried it around in a horizontal circle of about one inch radius with a uniform speed of five and a half revolutions per second, which gave therefore a linear velocity of the metal through the liquid of nearly three feet per second. The strip was suspended from the arm so as to hang vertically, and the area of its surface was known. The results are given in the appended table in the columns marked 2 and 3. It was at once apparent that the absolute rate of action was much greater than when the metal was stationary, as in Messrs. Gladstone and Tribe's method where the only mass motion of the liquid relatively to the plate was caused by gravitation. An inspection of columns 2 and 6, where their method was followed, will show this.

In column 3 are given the quotients of the actual weights divided by the percentages of silver nitrate. It is apparent that these

numbers tend toward a constant, and, in this respect, they show a marked contrast to the numbers in column 7.

The experiments were next varied by varnishing the copper on its convex side and holding it rigidly against the side of a beaker while its bare concave face was constantly swept by a rotating cylindrical brush, driven at uniform speed by clockwork. The results are given in columns 4 and 5, where, to secure a greater range for comparison, a different order of per cents was employed, and it is evident from column 5, that the absolute rate is less than for the rotation experiments, but is still much greater than for the gravitative record; also it is apparent that the quotients here also tend to approach a constant [.6].

The first two numbers in columns 3 and 5 depart widely from the others. This is due, I believe, to the necessity of removing the silver each time the copper was weighed to determine how much of it had been dissolved. When the solution is very weak, the silver crystals are so minute that it is practically impossible to remove them completely, while for larger crystals, made by stronger solutions, there is no such difficulty.

Now when the extreme difficulties of securing absolutely uniform rotation, of detaching the copper at a given instant, and of preventing accidental cross currents are considered, these numbers show (since they are the means of many trials) that the chemical action varies directly with the quantity of salt in solution, when the supply of fresh liquid to the surface of the plate is constant and independent of its strength. Within the limits of these experiments, the following law would appear to be true. *In metallic precipitations of dilute solutions, the chemical action varies directly as the mass, i.e., percentage, of the dissolved salt.*

The experimental work of Messrs. Gladstone and Tribe is above criticism. I made many determinations by their method, with the sole result of confirming their entire accuracy. How then can their law be reconciled with the above statement?

The explanation I venture to offer is the following:

When the plate is suspended in the liquid, a film of copper nitrate is at once formed against it. Now the access of fresh silver nitrate depends on the removal of copper nitrate; this film being heavier than the main solution begins to fall (a part also rises) and thus drags in fresh liquid from above to attack the copper. The rate at which it falls depends on its density, that is

on the quantity of copper dissolved, but it is resisted by the inertia of the surrounding fluid which it must displace.

Now in a second experiment let the percentage of silver nitrate be doubled; then, by the statement made above, the quantity of copper dissolved in a very small portion of time will also be doubled, and its density will be greater. The increase of density may be found from the tables of specific gravities of copper nitrate solutions. Storer's dictionary of solubilities gives the following:

| Per cents. of salt. | Densities. |
|---|---|
| 1. | 1.0059. |
| 2. | 1.0119. |
| 3. | 1.0192. |
| 4. | 1.0252. |

We see that the increment of the density rises a little more rapidly than the increase of the salt, so that the density of a four per cent solution, for example, is 2.11 times that of a two per cent solution. Therefore the film of copper nitrate will be more than twice as dense when the percentage of silver nitrate is doubled. The rate of motion of the film will, however, not be twice as great; for bodies, moving with *slow* velocity through a liquid, are found to experience resistances which vary as the square of the velocity. The density of the film has become more than twice as great, consequently the attraction between it and the earth has more than doubled. It is also evident that though the specific gravity of the silver salt is increased, still, the increment of the density of the copper solution over that of the silver solution will be more than doubled. Hence its velocity will become not two, but as the square root of two, which is 1.41 +: but as the relative density (or the relative increment) is really more than two, its square root will approach near 1.5.

The observed rate of action will be composed therefore of the two ratios, viz., twice the chemical action because of chemism, multiplied by one and a half because of gravitative action; or, when the per cent of silver salt is doubled, the quantity of copper dissolved will be tripled. But this is Gladstone and Tribe's law.

The above hypothesis leads to this conclusion. If the "2—3 law" is composed of two factors, one of which is chemism, and the other gravitation; then if another accelerating force could be substituted

for gravitation the law ought to change its form, if that force could be made a large one, for, the rate of movement of a body through water is determined by resistances which increase much faster than the square of the velocity when the latter is no longer small. Accordingly I mounted the precipitating vessel on an arm which permitted the whole to revolve in a vertical plane and with a velocity which gave a centrifugal force thirty times greater than the value of the acceleration of gravity. With this large force it was certain that the currents ought to increase much more slowly than in the ratio of the square root of 2. An inspection of columns 8 and 9 will show the results. In column 9 the numbers do not tend to approach a constant but slowly increase. They resemble in this respect the gravitation numbers in column 7, only their rate of increase is slower as it should be by theory. A mathematical analysis of these numbers, taking the 30 per cent one as a basis, agrees very closely with those calculated by the formula—that doubling the per cent of silver increases the rate of precipitation to 2.25 instead of to 3.

In conclusion, I think it is probable that the true law of chemical action, where one metal precipitates another, should be that the time during which one atom replaces another in a compound molecule is fixed, and hence that the rate of total chemical action varies directly as the mass of the reacting body in solution.

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## Preliminary analysis of the bark of Fouquieria splendens.

By Helen C. De S. Abbott, Philadelphia, Pa.

In the published proceedings of the Mexican Boundary Survey of 1859, conducted by General William H. Emory, are found numerous references to *Fouquieria splendens*. No region of equal extent presents more marked illustrations of the relations of the vegetation of a country to its topography and geology than that lying along the Mexican boundary line. The traveller traversing the desert table-lands will not fail to unite in his recollections of these tracts the dull foliage of the creosote bush, the palm-like Yucca, and the long thorny wands of the *Fouquieria splendens*. The vegetation of the El Paso basin and the Upper Rio Grande

valley is described as strikingly different from that of the immediately adjoining country: new and strange plants are seen on every side. Upon the table-lands many plants grow not to be found in the more fertile valleys; among these is *Fouquieria*, a tree locally known by its Mexican name ocotilla. A full description of the appearance of the plant is given in the Mexican Boundary Survey; also one in an article by Edward Lee Green.[1] The latter author describes *Fouquieria splendens* in these terms: "It is a splendid oddity and not more odd than beautiful, flourishing in great abundance in many places. It grows to the height of from eight to twelve feet, and in outline is quite precisely fan-shaped. The proper trunk, usually ten to twelve inches in diameter, is not more than a foot and a half high. A few inches above the surface of the sands this trunk abruptly separates into a dozen or more distinct and almost branchless stems. These simple stems rising to the height of eight or ten feet gradually diverge from one another, giving to the whole shrub the outline of a spread fan. Each separate stem is clothed throughout with short gray thorns and small dark green leaves, and terminates in a spike, a foot long, of bright scarlet trumpet-shaped flowers. The stems are not so thickly armed with thorns but that they can be handled if grasped circumspectly, and being very hard and durable, as well as of a convenient size, they are much employed for fencing purposes about the stage stations and upon the ranches adjoining the desert." The author states: "Give a skilful Mexican ocotilla poles and plenty of raw hide thongs and he requires neither nail nor hammer to construct a line of fence, which for combined strength, neatness and durability fairly rivals the best work of that kind done in our land of sawmills and nail factories."

The plant is botanically described under order *Tamariscineæ*, tribe III, *Fouquiereæ*, new genus and species.[2] For other sources of information see A Tour in New Mexico;[3] and in Plantæ Wrightianæ[4] Texano-Mexicanæ. The writer has not been able to find any notice of chemical studies made upon it.

The specimens of ocotilla, at the writer's request, were collected and transmitted from Lake valley, Southwest New Mexico, through

[1] Botanizing on the Colorado Desert, American Naturalist, 1880.
[2] Bentham and Hooker. Genera Plantarum.
[3] By Dr. N. Wislizenus.
[4] Gray, Smithsonian Contributions to Knowledge. Vol. iii. Part 1, p. 85 and Pt. ii. p. 68.

the kindness of Professor E. D. Cope. The portions of the stem, similar to those used in the analysis, vary in diameter from an inch to an inch and a half. The bark shows a thickness of over an eighth of an inch, and is of a sage color generally. The exterior surface is made rough by an interlacement of hard projecting material; some of the smaller stems are encircled with the gray thorns described, arising in regular series from the projecting portions of the bark. Between the interlacements are oblong and diamond-shaped intervals, which are filled with superimposed layers of a yellowish color and looking as if coated with a wax. They appear to be cemented together by a glistening substance which on warming the bark exudes and possesses a resinous or gum-like consistency.

In the present investigation, the scheme proposed by Dragendorff[5] has been followed out, with the exception of the maceration at the ordinary temperature; an apparatus similar to the one last devised by Tollens[6] has been used for the extractions. The air dried material reduced to a very fine powder was again dried at 100° C. giving 9.4 per cent. moisture, since the great importance of powdering the material for the various estimations as insisted upon by Dragendorff[7] was fully confirmed in these examinations. Quantitative determinations with ocotilla bark reduced to fine pieces gave 2 per cent. and 3.5 per cent. less than the percentage obtained from the estimations with the powdered substance. Determination of total ash gave 10.26 per cent.; a qualitative ash analysis showed the presence of calcium, magnesium, aluminum, potassium, sodium, and a trace of iron; sulphates, phosphates, and chlorides.

Ten grammes of the air-dried powder treated with petroleum spirit of boiling point 46° C. extracted a substance without aromatic odor, communicating to the liquid a light color. From 100 C.C. a measured portion was evaporated for determination of total amount of substances brought into solution. The residue dried at 100° C. gave 9 per cent, at 110° C. 8.87 per cent, at 120° C. 8.875 per cent and a loss of .125 per cent showing scarcely appreciable trace of volatile oil. The remainder of the petroleum spirit extract on evaporation at the ordinary temperature left a solid yellowish-green wax substance of specific gravity .984, melting from 84° C.

[5] Plant Analysis, Qualitative and Quantitative, G. Dragendorff, Ph. D. Translated from the German by H. G. Greenish, London, 1884.

[6] Zeitschrift f. anal. Chemie, XIV, 82, 1875, and XVII, 320, 1878.

[7] Loc. cit.

C. to 85° C., insoluble in water, slowly soluble in boiling 95 per cent alcohol, readily in absolute alcohol, in cold ether, chloroform, amyl alcohol, benzole, carbon disulphide, oil of turpentine, and linseed oil; slightly dissolved in aqueous alkalies, but not saponifying with them. It is colored yellow by nitric acid; acted upon by concentrated sulphuric acid, and not by hydrochloric acid nor aqua regia. By means of combining sulphuric acid and solvents, I was able to obtain several color reactions that may prove upon further investigation of value in identification of the different vegetable waxes. With Japanese wax, the only specimen of vegetable wax I could obtain, the color reactions differed in each test from the substance under consideration. The following color reactions were obtained with the petroleum spirit residue. When small fragments were stirred on a watch crystal with two or three drops of concentrated sulphuric acid of 1.84 sp. gr. the substance at once changed color to a clear garnet red and was slowly dissolved by the acid, the liquid remaining colored; with different portions of the red acid liquid stirred on a watch crystal with various solvents used in excess, it was noted as follows:—with absolute alcohol the color was instantly dissipated leaving a white precipitate; petroleum spirit discolored the acid solution, leaving no precipitate; ether discolored with gray precipitate; chloroform changed the red acid liquid to yellow, no precipitate; with benzole the red color was changed to snuff-brown gradually passing to red-brown; amyl alcohol gave a rose-pink and slowly passing through varying tints to a fine purple. So-called pure amyl alcohol was used and when tested did not give a color reaction alone with sulphuric acid. The petroleum spirit residue on boiling with absolute alcohol and when warm, thrown into several times its volume of cold water separated out as a white cloud.

Employing a method by which melissyl alcohol has been obtained from Carnaüba wax[8] the petroleum spirit residue was submitted to a like treatment. It was boiled with alcoholic potash and saponified, the alcohol distilled off and lead acetate added; a heavy light yellow-colored precipitate formed, and on boiling yellow masses separated out. They were washed, dried, and boiled with absolute ether. The filtered liquid on cooling deposited a yellow crystalline substance, which on heating on platinum foil turned black and dis-

[8] Liebig annalen, 183, p. 344, teste Watts Dict. Chem.

appeared. Beyond ascertaining the fusing point, solubilities, and color reactions, the substance was not further examined. It was found to fuse between 43° C. and 60° C., the greatest change occurring between 57° C. and 60° C.; to be soluble in chloroform and ether; scarcely soluble in cold absolute alcohol; very slightly soluble in boiling 95 per cent alcohol; not acted upon by nitric acid nor aqua regia. Sulphuric acid dissolved the substance and gave an orange color reaction discolored on adding alcohol, ether, chloroform, and ammonia to the acid liquid, with no precipitate; with amyl alcohol a pale rose-pink quickly fading, and with benzole a brown color, were obtained. The color tests differed from those obtained with the substance before saponification and treating with boiling ether, indicating that the petroleum spirit residue can be separated into at least two substances and possibly more, which remain to be determined by a future study.

The powder exhausted by petroleum spirit was dried and similarly treated with absolute ether as in the previous extraction. The ethereal extract of a greenish color gave an acid reaction with litmus, and on addition of alcohol the liquid became turbid. Spectroscopic examination failed to detect the characteristic chlorophyll bands. The ethereal residue on evaporation presented differences in color and solidity from the petroleum spirit residue. It was quite brittle, and was not appreciably softened at 120° C. It gave when dried at 100° C. 4.52 per cent of solids extracted, at 110° C. 4.44 per cent and at 120° C. 4.42 per cent. The residue when evaporated at ordinary temperature was insoluble in petroleum spirit, slightly soluble in 95 per cent alcohol, and carbon disulphide, quite soluble in cold absolute alcohol, amyl alcohol, chloroform, benzole, and oil of turpentine. Nitric acid gave no reaction. With sulphuric acid and small portions of the ethereal residue, I obtained a dark mahogany color. This solution on adding absolute alcohol was partially discolored, no precipitate. With ether the sulphuric acid solution gave a greenish precipitate, with amyl alcohol the acid solution was discolored changing to pale-red, then green. These tests showing in each case a wide difference in color reactions from those obtained with the petroleum spirit residue. The amount of solids taken up on treating the ethereal residue with water was .36 per cent. The aqueous liquid was neutral to litmus, portions tested for alkaloids gave negative results; on warming and addition of dilute sulphuric acid, Fehling's solution was reduced, indicat-

ing possibly glucosides. The portion insoluble in water was then treated with absolute alcohol. The liquid gave an acid reaction with test paper. A measured part of the liquid was evaporated and the weighed residue showed 1.6 per cent. of solids dissolved. The residue from the evaporated alcoholic liquid was partially dissolved by aqueous alkalies. It readily saponified with alcoholic soda, forming a soft brown soap, which on boiling with lead acetate yielded a yellow precipitate. This was collected on a filter and washed. When the precipitate was boiled with absolute ether and the filtrate allowed to slowly evaporate, a white organic crystalline substance separated out. Under the microscope particles of coloring matter were found to be interspersed among the crystalline structures.

The indications would show an acid resin to have been extracted by the ether.

The ten grammes of powdered bark, after exhaustion with petroleum spirit followed by absolute ether, were treated with absolute alcohol. A measured quantity of the alcoholic extract was evaporated in a weighed platinum dish, dried until weight noted was constant. After incineration the amount of ash was found to be .15 per cent of the original material. The alcoholic extract for determination of total amount of organic solids dissolved, was evaporated in a current of carbonic acid, when the residue dried gave 8.6 per cent and 7.98 per cent of solids respectively. A cloudiness formed on the addition of water to the residue, which cleared up on addition of alkalies. It was restored by acid. The aqueous liquid gave precipitates with calcium and lead salts. It reduced Fehling's solution on adding dilute acid and warming. Negative results followed tests for alkaloids. Treating with two volumes of absolute alcohol, according to Dragendorff for detection of gum, vegetable mucilage was separated. Tests failed to detect the presence of tannin.

The residue of the powdered bark, after exhaustion with absolute alcohol, was treated with cold water. A deep red mucilaginous liquid, which became frothy on shaking, was extracted. The amount of solids in this solution, on evaporating the liquid and weighing the residue, was found to be 19.11 per cent. In absence of acid or boiling, glucose was identified by Fehling's solution also by Mulder's test. A gum separated by absolute alcohol and quantitatively estimated, showed 4.8 per cent. of the amount of substances

dissolved in water. The powdered residue, after treatment with water, was macerated with dilute acid, and gave negative tests for alkaloids. The extractions with caustic soda for identification of albuminous substances, followed by chlorine water for the estimation of lignin and cellulose, have not yet been determined.

The results of the proximate analysis as so far completed may be stated as follows:

| | |
|---|---|
| Moisture . . . . . | 9.4 per cent. |
| Petroleum spirit residue . . | 9. |
| Ethereal residue . . . . | 4.52 |
| Alcoholic residue . . . . | 8.6 |
| Water residue . . . . | 19.11 |
| Total ash . . . . . | 10.26 |
| Alcoholic extract ash . . . | 00.15 |
| | 61.04 |

The difference of 38.96 per cent would include pectose, coloring matter, and cellulose or woody fibre.

A qualitative ash determination showed the presence of calcium, magnesium, albuminum, potassium, sodium, a trace of iron, sulphates, phosphates, and chlorides.

Petroleum spirit extracted a solid substance, yellowish-green in color, of sp. gravity .984, melting from 84° C. to 85° C. insoluble in water, slightly soluble in boiling 95 per cent alcohol, soluble in absolute alcohol, cold ether, chloroform, amyl alcohol, benzole, carbon disulphide, oil of turpentine, and linseed oil. It was slightly acted upon by aqueous alkalies; but readily saponified with alcoholic soda. Treating the soap with lead acetate and boiling the precipitate with ether, a yellow crystalline substance was obtained, melting from 43° C. to 60° C. Sulphuric acid combined with solvents gave characteristic and distinct reaction with the yellowish-green petroleum spirit residue, and with the crystalline substance separated from it.

A scheme has been proposed for the identification of various waxes, based upon quantitative experiments.[9] The examination rendered division into two groups possible, according to the solubilities of the waxes with chloroform. Again their action with

[9] Contributions to the Chemistry of several varieties of wax, by E. Hirschsohn. Pharmaceutical Journal and Transactions, Vol. x, March, 1880.

ether, and acetate of lead solution added to the alcoholic solutions, allow the several varieties of waxes to be distinguished from each other.

The petroleum spirit residue was submitted to the tests proposed in Hirschsohn's scheme. It was boiled with ten times its volume of chloroform and when cool the liquid became cloudy. By this test, the petroleum spirit residue was placed in the group with Carnaüba and Bahia wax. An ethereal solution of the petroleum spirit residue, on adding an equal volume of alcohol, remained clear. According to Hirschsohn's scheme,[10] an ethereal solution of Bahia wax similarly treated remains clear, and by this means, the wax is distinguished from Carnaüba wax, which it is said to resemble in most of its properties. The wax from *Copernicia cerifera*, the Canauba tree of Brazil, and Carnaüba wax obtained from the leaves of *Corypha cerifera*, are related very closely by their chemical properties and possibly are identical.[11]

Carnaüba wax is described as a clear yellow wax with a greenish tinge, and harder than beeswax. It contains a notable percentage of free melissyl alcohol and other alcohols very difficult to separate. Insoluble in water, it is dissolved with difficulty by alcohol and ether, though readily soluble in carbon disulphide and oil of turpentine. It is not acted upon by linseed oil; it is changed yellow by nitric acid; with sulphuric acid no appreciable effect. The melting point is variously stated from 82° C. to 85° C. The specific gravity from .998 to .999.

A table of the specific gravity of the different kinds of waxes, prepared by Dietrich[12], shows the density of animal wax to be notably low compared with vegetable waxes. Allen[13] states that the presence of vegetable wax in adulterations of beeswax is positively established if the density of the sample exceed .970.

By the method followed out in this analysis, petroleum spirit extracted from the powdered bark a substance of constant melting point, which is identified as a wax. It resembles, in its ethereal solution not clouding on addition of alcohol, Bahia wax; in melting point and specific gravity, Carnaüba wax; also the latter wax by

[10]Loc. cit.

[11]Gmelin. Handbook of Chemistry, Vol. xviii. Translated by H. Watts, London.

[12]E. Dietrich. Specific Gravity of wax. Journal of Chemical Society, 1882, Vol. xlii, p. 1139.

[13]A. H. Allen. Commercial Organic Analysis. (Also see in same work Tables of sp gr. waxes.)

its insolubility in water and action with nitric acid. It differs from Carnaüba wax in its greater degree of solubility in absolute alcohol, ether, and aqueous alkalies. Linseed oil is an active solvent for it, but does not dissolve Carnaüba wax. The color reactions of the petroleum spirit residue with sulphuric acid have been described above. It is stated that sulphuric acid produces no effect with Carnaüba wax.[14]

The wax obtained from the bark of *Fouquieria splendens* differs generally in its properties from known vegetable waxes, and is evidently a new wax, peculiar to this plant. I propose that it be called Ocotilla wax.

In the ether, absolute alcohol, and water extracts, the presence of an acid resin, a white crystalline substance, gum resin, glucose, possibly glucosides, gum, and a red coloring matter were indicated.

The investigations described in the preceding pages were conducted in the Chemical Laboratory of the Philadelphia College of Pharmacy, August and September, 1884.

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THE DENSITY OF SOLID CARBONIC ACID. By Prof. JAMES DEWAR, Cambridge, England.

[ABSTRACT.]

THE object of this paper is to compare the theoretical density of the solid as deduced from the formulæ of Clausius, with experimental number found by the author.

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THE COMPOSITION AND METHODS OF ANALYSIS OF HUMAN MILK[1]. By Prof. ALBERT R. LEEDS, Stevens Institute, Hoboken, N. J.

IN a previous paper, "On Infant Foods," which I read before the College of Physicians of Philadelphia, May 2, 1882, I alluded briefly to the investigation then in progress upon the composition of human milk, and gave a tabular statement of the minimum, maximum, and average results of the analysis of forty-three samples, the total number of analyses which I had made up to that date.

[14] A. B. Prescott. Outlines of Proximate Organic Analysis.

[1] The tables and chart are from electrotypes of advance sheets from the Transactions of the College of Physicians of Philadelphia.

Since then I have analyzed thirty-seven more samples, and have verified the results by a critical examination of the various methods of analysis which are in use at the present time.

In the beginning of my previous paper, I asked the question, "What is human milk?" and stated that to answer this question satisfactorily, we should know at least three things: 1st, All the constituents; 2d, Their relative proportion; 3d, Their chemical and physiological properties. It is not my present object to discuss the first and third points, except in the light of the following isolated results which were only incidental to the main object of the present inquiry.

The albuminoids and fat of a large number of samples, as obtained by precipitation with Ritthausen's solution, were extracted with ether, until the albuminate of copper ceased to give up any further traces of fat to the solvent. It then became after drying a very light-green amorphous powder.

In order to separate the albuminoids, this powder was digested with very dilute hydrochloric acid, which carries some of the organic matter into solution along with the copper. The residue, after washing and drying at 100°, formed brownish, somewhat brittle, amorphous masses.

The percentage of cupric oxide contained in this albuminate of copper was found in two analyses to be 20.93 per cent and 20.63 per cent. The ultimate analyses of the albuminate, after deducting cupric oxide, yielded the following results:—

| | I. Per cent. | II. Per cent. |
|---|---|---|
| Carbon | 49.07 | 49.17 |
| Hydrogen | 7.15 | 7.22 |
| Nitrogen | 14.67 | .... |
| Sulphur | 1.06 | 1.15 |

Two analyses of the total albuminoids, left behind after the foregoing treatment of the albuminate of copper with dilute hydrochloric acid, gave the following figures:—

| | I. Per cent. | II. Per cent. |
|---|---|---|
| Carbon | 52.89 | ..... |
| Hydrogen | 7.02 | ..... |
| Nitrogen | 13.64 | 13.50 |
| Sulphur | 1.49 | ..... |

The albuminoids, separated by hydrochloric acid from the copper albuminate, were digested with 50 per cent alcohol, at the boiling-point. On cooling, the filtered solution deposited a white, flocculent,

voluminous precipitate, whilst the residue on the filter formed a somewhat brownish mass.

This precipitate would correspond to the "caseo-protalbin" of Danilewsky (*Jahresb. der Thierch.* 1880, 186), and the residue, which was much the larger in amount, to his "caseo-albumen."

An analysis of the caseo-protalbin gave:—

| | Per cent. |
|---|---|
| Carbon | 55.86 |
| Hydrogen | 6.07 |
| Nitrogen | 17.17 |

An analysis of the "caseine," obtained by Makris in quite a different manner from woman's milk, yielded for its composition, carbon 52.35 per cent; hydrogen 7.27 per cent; and nitrogen 14.65 per cent.

The foregoing analyses render evident that the bodies examined are not homogeneous, and in every case the process of separation left behind mixtures of substances the true nature and composition of which are at present unknown. Moreover, the deportment and properties of the bodies examined are such as to lead one to the conclusion that the investigation was being conducted, not upon bodies in the condition and with the properties which they possessed originally in woman's milk, but upon substances whose composition and properties had been altered by the operation of the reagents employed.

It had been the intention of the author to endeavor to isolate the various constituents, at present very imperfectly known, of the fat of human milk. This desire had been increased by the fact that the ethereal extract of the copper albuminate, obtained from numerous samples, although not by any means from all, was colored emerald-green by some copper salt. As to the chemical nature of this copper salt, going as it does in perfect solution in ether, I have no knowledge. Unfortunately, the entire mass of fats was lost by accident in the early stages of manipulation, and I shall have considerable difficulty in again procuring sufficient material to work upon. No sample of cow's milk which I have analyzed yielded to ether an emerald-colored solution. The unknown body is peculiar to woman's milk.

### Methods of Analysis.

Passing by the methods of analyses which were employed when the nature of the difficulties to be overcome was imperfectly under-

stood, and omitting from discussion in this paper the earlier results as obtained by Meggenhofen, Payen, Henri and Chevallier, L'Héritier, Quevenne, Simon, Clemm, Sherer, Donné, Heilen, Regnault, and Lehmann, the first method claiming our attention is that made use of by Vernois and Becquerel, in their essay "Du Lait chez la Femme," Paris, 1853.

Although regarded by the authors of the process as the smallest which they could employ, the amount of milk regarded by V. and B. as necessary for analysis is excessive, being 60 grammes.

*Total Solids.*—Of this, 30 grms. are taken for determination of total solids, which are found by evaporation to constant weight at 80° C. It is evident that the evaporation of so large an amount at so low a temperature not only requires very many hours, but presents great difficulties in the way of expelling the least traces of moisture.

*Fat.*—The total solids are exhausted on a filter with ether. The loss in weight is set down as fat. Or the ethereal extract after evaporation gives the weight of fat directly.

The estimation of fat by loss of weight involves numerous sources of error. And even the direct estimation according to this method is erroneous, inasmuch as ether very partially exhausts a dried residue of this nature. Consequently, the figures obtained by V. and B. for fat are much too low, the average in 89 samples being only 2.67 per cent.

The other 30 grms. are coagulated by boiling with some drops of acetic acid. The filtrate contains sugar, extractive matters and soluble salts.

*Milk sugar.*—Its determination by the saccharimeter, as performed by V. and B., gives less accurate results than those obtained by direct chemical methods.

*Albuminoids.*—The authors regard the nature of the extractive matters as so entirely unknown as to make their determination by analysis impossible, and set down under one head what they denominate "caseum and extractive matters." Its amount is found by subtracting the sum of the weights of fat, sugar and ash, from the total solids. If it were possible by their method to determine these four quantities correctly, the difference, which they style caseum united with extractive matters, would be the albuminoids. But, otherwise, the difference represents the algebraic sum of the errors committed in the various determinations, and this difference, in the present instance, the amount of fat and sugar as stated by

V. and B. being much too low, is correspondingly too high, being 3.92 per cent.

*Analysis by the same method as that usually employed for Cows' Milk.*—This method, which is practised by some of the public analysis of New Jersey and New York, and which is a somewhat modified form of Wanklyn's, will be found stated in Cairns's Quantitative Analysis, p. 204.

The results obtained on sample of woman's milk, Laboratory No. 1133, were as follows:—

| | Per cent. |
|---|---|
| Ash | 0.21 |
| Fat | 3.62 |
| Albuminoids | 2.60 |
| Milk sugar | 8.19 |
| Total solids by summation | 13.62 |
| Total solids by evaporation | 13.63 |

The fat, as thus determined, is too low, although it was extracted by digesting the solids left after evaporation with boiling ether six times, and with cold ether as many times more.

The sugar is too high. After weighing, it was redissolved in water, and the amount of albuminoids contained in it determined. This was 0.78 per cent, which, subtracted from the sugar, as determined in accordance with the method, left 7.41 per cent, which is the correct result.

The albuminoids are also too high, and the excess is still greater when the albuminoids contained in the sugar are added to those as determined in accordance with the method, the total being 3.38 per cent. This excess is due to fat.

Correcting the results, as found directly by the method, by the results obtained by separately analyzing the various educts, we have:—

| | Per cent. | Per cent. |
|---|---|---|
| Fat, determined by method | 3.62 | |
| Fat, extracted from caseine residue | 2.13 | |
| Actual fat | | 4.80 |
| Albuminoids, determined by method | 2.60 | |
| Albuminoids, contained in sugar | 0.78 | |
| Sum of albuminoids | 0.03 | |
| Deduct fat found in caseine residue | 2.13 | |
| Actual albuminoids | | 1.30 |
| Sugar, determined by method | 8.19 | |
| Deduct albuminoid found in sugar | 0.78 | |
| Actual sugar | | 7.41 |
| Ash | | 0.21 |
| Total solids, by summation | | 13.62 |
| Total solids, by direct evaporation | | 13.63 |

*Determination of the Albuminoids by Precipitation with Alcohol.*[2]—20 cc. of dilute acetic acid are added to weak acid reaction, then four volumes of strong alcohol, the mixture well stirred, allowed to settle during an hour, and filtered upon a weighed filter. The precipitate is washed six or eight times with cold sixty per cent alcohol, then with ether, dried at 120–125° C. and weighed. The alcoholic filtrate is evaporated to small volume, the resultant precipitate transferred by means of sixty per cent. alcohol to a weighed filter, washed repeatedly with the same alcohol, and finally with ether. These filtrates are again evaporated to a small volume, the precipitate obtained dissolved in water, an aqueous solution of tannic acid added, the precipitate so obtained transferred to a weighed filter, washed first with water, then with alcohol and ether, dried at 120° and weighed. The three precipitates together contain all the albuminoids. They must be ignited, and the amounts of ash deducted. This method gives too low results when the addition of tannic acid is omitted. The trial of this method, as performed on sample, Laboratory No. 1133, yielded the following results:—

| | Per cent. |
|---|---|
| Albuminoids in first precipitate | 0.66 |
| " " second precipitate | 0.55 |
| " " third " | 0.42 |
| Total albuminoids so determined | 1.63 |

The analysis of these albuminoids yielded:—

| | Per cent. |
|---|---|
| Fat | 0.00 |
| Milk-sugar | 0.43 |

Deducting this amount of milk-sugar, we have:—

| | Per cent. |
|---|---|
| Total albuminoids as found | 1.63 |
| Deducting milk-sugar | 0.43 |
| Albuminoids actually present | 1.20 |

Distilling off the alcohol and ether from the first and second precipitates and determining the milk-sugar in the collected filtrates from the albuminoids, I obtained:—

| | Per cent. |
|---|---|
| Fat | 4.80 |
| Milk-sugar | 6.98 |

These results make it evident, what, indeed, was feared during the whole course of the analysis by this method, that notwithstand-

[2] Handb. der Physiolog. Chem. Anal. Berlin, 1883, p. 491. Hoppe-Seyler.

ing the great expenditure of time in washing these precipitates, the washing was incomplete, and some milk-sugar was left behind. This supposition is confirmed by the fact, that upon adding the milk-sugar contained in the albuminoid precipitates to that contained in the filtrates, the sum is the correct percentage of sugar.

*Determination of the Albumen and Peptone by Precipitation with Magnesium Sulphate.*[3]—The assumption upon which this method is founded is that when crystallized magnesium sulphate is added to milk to the point of complete saturation, the caseine is completely precipitated, whilst the albumen and peptone are not. In the execution of the method, 40 c.c. or a saturated solution of magnesium sulphate are added to 10 grms. of milk, and afterwards crystals of the same salt are added in slight excess of the maximum quantity which can be made to enter into solution. After standing several hours with frequent stirring, the precipitate is transferred to a beaker and washed six or eight times with a saturated solution of magnesium sulphate. The collected filtrates are then diluted with water, a drop or two of acetic acid added, heated to boiling for a few minutes, filtered through a weighed filter, the precipitate washed first with water and afterward with alcohol, dried along with the filter at 120° to 125°, weighed and ignited. By subtracting the weight of ash from that of the precipitate, the amount of albumen is determined.

In the filtrate the peptone can be precipitated by means of tannic acid, or by phospho-tungstic and sulphuric acids.

I failed entirely in an attempt to perform an analysis by this method. Owing to the great density of a saturated solution of magnesium sulphate the caseine did not precipitate, but formed a layer on the surface of the liquid, and so slow was the operation of filtration that I did not succeed in completely washing the caseine during the course of several days.

*Haidlen's Method, as modified by Christenn. Total Solids.*—Instead of drying the milk at 110° with one-fifth of its weight of powdered gypsum, as proposed by Haidlen, Trommer proposed the use of pulverized marble, and Christenn employed powdered glass, the drying being conducted at 95° to 100° instead of 110°. Christenn found that the hygroscopic nature of the gypsum and

[3] Handb. der Physiol. Chem. Anal. p. 493. Hoppe-Seyler.

its solubility in alcohol gave rise to errors, the latter property raising the percentage of milk-sugar and diminishing the percentage of albuminoids.[4]

*Other Constituents.*—To 10 grms. of milk add 10 c. c. ether and 20 c. c. alcohol, mix thoroughly, collect the precipitated albuminoids on a filter, and wash with a mixture of ether and alcohol (1 : 2) until the filtrate runs through clear. The precipitate, dried at 95° to 100°, gives the weight of albuminoids and insoluble salts. By ignition, the weight of the latter is obtained, and the difference gives that of the albuminoids. The weight of evaporated filtrates gives the combined weight of the fat, milk-sugar, and soluble salts. The loss of weight after extraction with ether gives the fat. The soluble salts and sugar are ignited, the residue treated with hot water, the solution evaporated to dryness, and ignited. The weight of this ignited portion gives the soluble salts, and the milk-sugar is found by difference.

NOTE. In the trial of this method I did not wash the precipitate of albuminoids and insoluble salts on the filter, but by decanting. The precipitate was shaken up six or eight times with the mixture of alcohol and ether, and the latter then pipetted off through a weighed filter. Finally, the albuminoids were thrown on the filter and washed exhaustively with the same mixture. The method of decantation is more rapid and thorough, but even with its aid and with the use in all of 250 c. c. of the mixed solvent, the washing of the albuminoids was incomplete, as shown by the following results of an analysis performed upon sample, Laboratory No. 1133.

Analysis according to the Haidlen-Christenn method :—

| | Per cent. |
|---|---|
| Fat | 2.90 |
| Albuminoids | 2.19 |
| Sugar | 8.23 |
| Ash | 0.21 |
| Total solids | 13.53 |

These various educts of the Haidlen-Christenn method were analyzed and separated into their individual constituents. The albuminoids were exhausted with ether, and the fat determined in the ethereal solution. The residue was then exhausted with water, and the sugar determined in the aqueous extract. In the final

[4] The addition of gypsum, marble, glass, sand, etc., is unnecessary and a source of error.

residue, containing according to Haidlen the sugar, the nitrogen was determined directly, and multiplied by 6.25 to obtain the percentage of albuminoids. The nature of the errors inherent in the method is strikingly shown when the corrected results obtained in this manner are compared with those stated in the preceding table:—

| | Per cent. | Per cent. |
|---|---|---|
| Fat, extracted from the albuminoids | 0.76 | |
| Fat, extracted from sugar residue | 2.90 | |
| Fat, total as thus found | | 3.66 |
| Albuminoids, determined by method | 2.19 | |
| Deducting fat in albuminoids | 0.76 | |
| Deducting sugar in albuminoids | 0.16 | |
| Actual albuminoids | | 1.17 |
| Sugar in albuminoids | 0.16 | |
| Sugar in final residue | 7.10 | |
| Actual sugar | | 7.26 |
| Ash | | 0.21 |
| Total solids, as found by summation | | 12.30 |
| Total solids, as found by evaporation | | 13.56 |
| Loss | | 1.26 |

This loss of 1.26 per cent represents fat, which I did not succeed in perfectly exhausting from the sugar residue after evaporation to constant weight, although the treatment with ether was performed very many times.

*Meigs' Method.*[5] *Total Solids and Ash.*—Pipette off 5 c. c. of milk into a platinum dish and weigh. Evaporated to dryness on a water-bath to constant weight. Incinerate, best over a blast-lamp, and weigh the ash.

*Fat.*—Weigh off 10 c. c. in another dish, and wash with the aid of 20 c. c. of water into a tall 100 c. c. stoppered cylindrical graduate. Add 20 c. c. ether, stopper, shake for five minutes, then add 20 c. c. alcohol, and shake five minutes more.

Allow the cylinder to stand until the ether has risen to the top, pipette off, add 5 c. c. ether, shake, allow to separate, pipette off and repeat this operation five times. Evaporate off the ether in a weighed dish; the increase in weight is fat.

*Caseine and Sugar.*—The remaining contents of the graduate, after the ethereal solution of fat has been removed, are washed into a platinum dish and evaporated to dryness on a water-bath. The residue is treated with boiling-water, and allowed to stand.

[5] Philadelphia Medical News, June, 1883.

The undissolved caseine precipitates, the solution of sugar is poured off. This latter is again evaporated to dryness, and the same process of settling and decantation repeated. This must be done four or five times, until it is found that when boiling water is poured upon the dry sugar it dissolves completely, no flocculi of caseine being seen in suspension. The caseine residue is then, after being dried, treated once or twice with boiling water to extract sugar. This sugar is added to the main portion. Both caseine and sugar are then evaporated over the water-bath to constant weight, incinerated over a blast-lamp, and the losses in weight give the amounts of caseine and sugar respectively.

*Experimental Trial of Method.—Total Solids.* In the weighing out of milk it must be poured directly into the dish in which it is weighed. If a pipette be used, the milk leaves minute particles upon its walls, and the alteration in composition thus produced is the greater, the more extensive the wetting surfaces of the measuring vessel.

Evaporation to dryness on a water-bath to constant weight is tedious, usually requiring three hours, and is neither so accurate nor so expeditious as the method of coagulation with alcohol.

Thus with sample No. 1133 :—

To 5.1195 grms. milk added 8 c.c. alcohol, evaporated to dryness on water-bath, an operation requiring one-half hour, and then to constant weight in air-bath at 105°, requiring with intervals for weighing one hour longer.

Loss of weight 0.699 grm. or 13.56 per cent.

Compare with this the results obtained by direct evaporation without coagulation.

Evaporated 5.059 grms. of same milk for three hours on water-bath.

Loss of weight, 0.6985 grm. or 13.81 per cent.

Dried the same for two hours longer in air-bath at 105°. The weight decreased to 13.59 per cent.

Dried the same for two hours longer at 103.° The weight decreased to 13.56 per cent. In other words, at the expiration of seven hours, I had obtained the same constant weight as I had found by the method of coagulation at the expiration of one and one-half hours.

The explanation of the difficulty of evaporating milk without

addition of any kind is evident, the caseine coagulated by heat forming a skin upon the surface of the milk which renders any further evaporation very difficult. Alcohol, on the other hand, divides the milk into fine coagula, which readily permit the escape of moisture.

*Fat.*—When water is present, ether will extract not only fat, but substances soluble in water. This was probably the case in the present instance, and experiment confirmed the conjecture. After distilling off the impure ether, drying the fat to constant weight at 105° and weighing, the fat thus obtained was redissolved in *absolute* ether. In every trial a residue was left behind. This residue dissolved readily in water. It proved to be milk-sugar, and its percentage was determined and added to that found elsewhere.

*Caseine and Sugar.*—The method has two objections. The albuminoids of milk, and more especially of women's milk, are partly soluble in boiling water, and cannot be perfectly separated from milk-sugar by its use. In the second place, the finely-divided albuminoids left after evaporation to dryness and treatment with boiling water cannot be accurately separated by the crude method of settling and decantation. As a result, in case the albuminoids are washed in this manner so completely that they do not contain any milk-sugar, their amount will be much too low, while that of the sugar will be correspondingly too high. The percentage of albuminoids in the milk-sugar was determined by direct determination of contained nitrogen in the following test analyses.

An attempt was made to separate the albuminoids by decantation through a weighed filter, but the process was extremely tedious, the albuminoids so coagulated quickly gumming up the filter paper.

The results obtained were as follows, several analyses being made of the same sample, No. 1133.

| | Per cent. |
|---|---|
| Fat, originally obtained | 4.77 |
| Fat, after redissolving in absolute ether | 4.66 |
| Containing by direct determination, milk-sugar | 0.10 |
| Fat as originally obtained | 4.52 |
| Fat, after redissolving in absolute ether | 4.48 |
| *1st Trial.* | |
| Albuminoids in residue | 0.79 |
| Albuminoids in milk-sugar | 0.63 |
| Total albuminoids | 1.42 |

*2d Trial.*

| | |
|---|---|
| Albuminoids on weighed filter | 0.36 |
| Albuminoids in milk-sugar | 0.71 |
| Total albuminoids | 1.07 |

*3d Trial.*

| | |
|---|---|
| Sugar as originally determined | 8.30 |
| Add sugar contained in fat | 0.34 |
| | 8.64 |
| Deduct albuminoids contained in milk-sugar | 0.72 |
| Actual milk sugar | 7.92 |

*Summary of Analyses.*

| | Per cent. (1) | Per cent. (2) |
|---|---|---|
| Ash (not with blast) | 0.21 | 0.21 |
| Fat | 4.77 | 4.83 |
| Albuminoids | 0.79 | 0.36 |
| Sugar | 8.01 | 8.30 |
| | 13.78 | 13.69 |

The results obtained by Meigs's method will always differ from those by Hoppe-Seyler's, Haidlen's, and Christenn's methods, and from Ritthausen's method, by giving necessarily a lower percentage of ash, a higher percentage of fat, a lower amount of albuminoids, and a larger percentage of milk-sugar. These differences are inevitable, and depend upon errors inherent in the method.

*Gerber-Ritthausen's Method.*—After using for a considerable length of time the methods of milk analysis in common use, the author was led by a comparison of the results obtained thereby with those found by Ritthausen's method to abandon the other methods and adopt Ritthausen's. The latter, as modified by Gerber, has now been in constant use in his laboratory for more than two years, and hundreds of analyses have been performed in accordance with it. The author regards it as the only method known at the present time, which is precise and rigidly accurate. Moreover, it is so rapid, and, when familiar, so easy of execution, that its employment soon becomes a source of pleasure and satisfaction.

*Details of Method. Total Solids.*—Weigh off 5 grms. of milk in a tared covered platinum capsule. Coagulate with absolute alcohol (about 3 c.c. are used), and evaporate to dryness on water-bath. Transfer to drying-oven, and keep at 105° C. until constant weight is attained.

*Ash.*—Ignite the residue first over a small flame, and finally at a dull-red heat. Cover the dish, cool in the desiccator, and weigh.

*Albuminoids.*—Dissolve 63.5 grms. pure sulphate of copper in a liter of water. Prepare also a potash solution containing 50 grms. caustic potash in 1 liter.

Weigh out 10 grms. of milk in a covered beaker glass, and dilute with 100 c.c. water. Add 2.5 to 3 c.c. of the copper solution. Then run in sufficient potash to exactly neutralize the excess of sulphate, which will require about 1.25 to 1.5 c.c of the potash. The coagulated albuminoids settle immediately, leaving the liquid clear. In testing the reaction, the stirring-rod which has been washed and withdrawn from the solution as soon as the potash has been stirred in, is dipped into the clear supernatant liquid. A drop of this liquid should turn neutral test-paper neither blue nor red. Care should be exercised not to allow the stirring-rod to bring up particles of the coagulum, since these interfere with the reaction. The clear liquid is then decanted through a filter-paper, previously dried at 110°, and weighed in a weighing-flask. The precipitate is then stirred up with 100 c.c. water, allowed to settle, the supernatant liquid again decanted through the filter, and, finally, the precipitate is washed upon it. The beaker is thoroughly cleansed with a rubber washer, and all these filtrates, amounting to about 240 c.c., are finally made up to exactly 250 c.c. for the determination of milk-sugar.

The filter paper containing the precipitate is then opened out upon a large watch-glass, and, after drying to a certain point, is divided up into small particles by a platinum spatula, and this comminution is repeated from time to time until finally the whole mass becomes a fine powder.

*Fat.*—The filter paper containing the precipitate is gathered up and placed loosely in a proper funnel. The beaker-glass used for the precipitation is washed out with ether to dissolve any traces of fat adhering to it, and these ethereal washings are poured through the funnel and allowed to run into a small weighed flask, with which the funnel is connected by a ground-glass joint. The funnel is then connected with a return cooler, the flask carefully heated by a water-bath, and the filter paper is made to swim in the ether condensed in the funnel for about an hour, when the extraction of fat will be complete. The ether is distilled off, the

flask dried at a temperature of 105°, cooled in a desiccator, and weighed. Its increment in weight gives the amount of fat.

*Albuminoids.*—The residue in the filter is dried at 110°, and weighed in the weighing flask until constant weight is attained. It is then ignited in a platinum crucible, and the weight of ash deducted. The loss of weight is the amount of albuminoids.

*Milk Sugar.*—This is determined in the filtrate by Fehling's solution. The figures thus obtained are identical with those found by evaporation of the filtrate to dryness, igniting, and subtracting ash.

In case the above method is carefully followed, the sum of the several constituents as separately determined will not differ by an appreciable quantity from the amount of solid matter as determined directly by evaporation. Thus, it will be seen from the accompanying table, giving the results of 62 separate analyses of human milk (excluding Laboratory No. 1063 as being manifestly affected by some accidental error), the maximum difference is 0.21 per cent.

The average error, as determined by ordinary arithmetical methods, is 0.001 per cent. The probable error of any individual analysis, as determined by the method of least squares, is a difference of 0.0098 per cent. in the sum of the several constituents as found by addition, and the sum as determined by direct evaporation.

This close agreement does not itself prove the accuracy of the methods employed, but, in connection with the fact that an analysis of the fat showed no trace of albuminoids or sugar, that an analysis of the albuminoids revealed no sugar or fat, and that an analysis of the sugar showed no albuminoids or fat, it does afford such proof.

The only serious objection to the method is that, in the precipitation of the albuminoids by Ritthausen's solution, hydrated basic sulphate of copper is precipitated at the same time, and that this hydrate does not lose its water at the temperature at which drying of the albuminates is effected. Hence, the weight obtained would be in excess of the true amount. This objection is not borne out by the results of analyses of the precipitated cupric albuminate, since I have failed to detect in it the presence of more than traces of hydrated basic sulphate.

### History of Samples Analyzed.

Samples 42 to 55 inclusive were obtained by Dr. K. Parker from inmates of the Infants' Asylum of New York; all the others were obtained by Dr. A. M. Thomas, Chief of Medical Staff of the Emigrants' Asylum and Hospital. Both of these physicians have given their personal attention to the collection of the samples, and in every instance tabulated the physical history of the mother under the following heads:—

I. Mother's name and nationality.
II. Married or single.
III. Age.
IV. Color of hair, etc.; blonde or brunette.
V. Period of lactation.
VI. Right or left breast, or both.
VII. Quantity obtained.
VIII. Time after last nursing.
IX. Time of day.
X. Number of parturitions.
XI. Presence or absence of menstruation.
XII. Present or former illnesses. Child-bed convalescence.
XIII. Physical antecedents of mother and parents.
XIV. Mother's diet.
XV. Health of infant.
XVI. Weight of infant at birth, and at collection of sample.
XVII. Age of infant.

It is not necessary to give in detail all these statistics. The mother's diet in every instance was simple, but abundant and nutritious. Only normal milks were analyzed, such as came from healthy women; these presented, when submitted to the microscope, a normal appearance.

The physical history of mothers and infants is given, as far as our present purposes require, in the accompanying tables.

TABLE I.—HISTORY OF SAMPLES ANALYZED.

| I. | II. | III. | IV. | V. | VI. | | VII. | VIII. | IX. | X. | XI. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Mother's age. | Nationality | Color of hair. | Period of lactation. | Breast. Right | Breast. Left | Interval since nursing. | Parturitions. | Infant's weight. At birth. | Infant's weight. At present. | Infant's age. |
| 13 | 28 | German | Brown | 1 day | .... | L. | 2 hours | 1 | 6 lbs. 5 oz. | ..... | 3 days. |
| 14 | 28 | German | Dk. b'wn | 1 " | .... | L. | 2 " | 2 | 6 " 12 " | ..... | 3 " |
| 7 | 19 | Irish | Dk. b'wn | 2 days | ½ R. | ½ L. | 5 " | 1 | 5 " 11 " | ..... | Died. |
| 18 | .. | Nos. 7–35 | ..... | 6 " | ½ R. | ½ L | | | | | |
| 28 | .. | same | ..... | 19 " | .... | L. | | | | | |
| 35 | .. | mother | ..... | 29 " | ½ R. | ½ L. | | | | | |
| 47 | 26 | American | Brown | 2 " | ½ R. | ½ L. | 2 " | 1 | 9 " 6½ " | ..... | 3 days. |
| 6 | 33 | Pole | Dk. b'wn | 2 " | R. | .... | 5 " | 9 | 7 " 0 " | 6 lbs. 12 oz | 4 " |
| 38 | 20 | German | Brown | 2 " | ½ R. | ½ L. | 3 " | 1 | 8 " 11 " | | |
| 15 | 23 | German | Light | 3 " | .... | L. | 2 " | 1 | 9 " 15 " | ..... | 5 " |
| 16 | .. | No. 15 to | A | 5 " | .... | L. | | | | | |
| 26 | .. | No. 30 | typical | 13 " | .... | L. | 2 " | | | | |
| 29 | .. | same | Blonde | 17 " | .... | L. | | | | | |
| 30 | .. | mother | ..... | 27 " | ½ R. | ½ L. | | | | | |
| 40 | 24 | Negress | Black | 3 " | ½ R. | ½ L. | 20 min. | 1 | 6 " 0 " | ..... | 4 " |
| 64 | 24 | Hungarian | Black | 3 " | R. | .... | 30 " | 2 | 8 " 6 " | ..... | 4 " |
| 8 | 29 | German | Lt. b'wn | 4 " | .... | L. | 4½ hours | 1 | 8 " 4 " | 7 " 12 " | 5 " |
| 45 | 22 | American | Brown | 5 " | ½ R | ½ L. | 2 " | 1 | 5 " 13½ " | ..... | 5 " |
| 67 | 28 | Scotch | Fair | 5 " | ½ R. | ½ L | 30 min. | 3 | ..... | ..... | 5 " |
| 41 | 23 | Irish | Black | 6 " | ½ R. | ½ L. | 30 " | 1 | ..... | ..... | 8 " |
| 21 | 18 | English | Black | 8 " | R. | .... | 1 hour | 1 | ..... | ..... | 9 " |
| 32 | 28 | German | Dk. b'wn | 10 " | ½ R. | ½ L. | 0 min. | 5 | ..... | 9 " 0 " | 10 " |
| 34 | 23 | German | Brown | 10 " | ½ R. | ½ L. | 1 hour | 2 | ..... | 7 " 8 " | 10 " |
| 33 | 23 | Irish | Dk. b'wn | 11 " | ½ R. | ½ L | 0 " | 1 | ..... | 8 " 4 " | Dead. |
| 65 | .. | Dane | Light | 12 " | ½ R. | ½ L | 1 " | 1 | ..... | 7 " 12 " | 13 days. |
| 4 | 23 | Irish | Dk. b'wn | 13 " | .... | L. | 3 hours | 2 | 7 " 5 " | 7 " 10 " | 14 " |
| 39 | 23 | Irish | Brown | 13 " | ½ R. | ½ L. | 0 " | 2 | ..... | ..... | Dead. |
| 48 | 22 | American | Red | 17 " | ½ R. | ½ L. | 2 " | 1 | ..... | 7 " 1½ " | 17 days. |
| 31 | 20 | German | Dk. b'wn | 19 " | ½ R. | ½ L. | ½ hour | .. | 4 " 14 " | 5 " 2 " | 21 " |
| 24 | 29 | Italian | Black | 20 " | ½ R. | ½ L. | ½ " | 2 | ..... | ..... | 21 " |
| 9 | 29 | Irish | Brown | 22 " | .... | L. | 5 hours | 5 | 6 " 10 " | 8 " 8 " | 24 " |
| 51 | 16 | American | Dk. b'wn | 23 " | .... | L. | 2 " | 1 | 9 " 2 " | ..... | 23 " |
| 68 | 22 | German | Lt. b'wn | 23 " | ½ R. | ½ L. | 1 hour | 1 | ..... | 6 " 3 " | 24 " |
| 3 | 19 | German | Brown | 25 " | .... | L. | 4½ hours | 1 | 7 " 0 " | 7 " 8 " | 27 " |
| 5 | 21 | Irish | Brown | 26 " | ½ R. | ½ L. | 6 " | 1 | 6 " 12 " | 7 " 8 " | 27 " |
| 2 | 21 | Irish | Dk. b'wn | 27 " | R | .... | 2 " | 2 | 6 " 2 " | 8 " 3 " | 29 " |
| 66 | 25 | German | Dk. b'wn | 30 " | ½ R. | ½ L. | ½ hour | 2 | ..... | ..... | 30 " |
| 12 | 23 | Irish | Brown | 41 " | .... | L | 5 hours | 1 | 8 " 12 " | 8 " 13 " | 44 " |
| 1 | 19 | German | Brown | 45 " | ½ R. | ½ L. | 5 " | 1 | 7 " 8 " | 8 " 2 " | 45 " |
| 17 | .. | same as 1 | ..... | 49 " | ½ R. | ½ L. | ..... | .. | ..... | 8 " 5 " | |
| 11 | 18 | German | Lt. b'wn | 46 " | .... | L. | 3 " | 1 | 6 " 0 " | 8 " 0 " | 48 " |
| 20 | 30 | Slavonic | Brown | 50 " | ½ R. | ½ L. | ½ hour | 1 | 5 " 8 " | 9 " 8 " | 52 " |
| 23 | 26 | Bohemian | Brown | 53 " | R. | .... | 1 " | 6 | ..... | ..... | 55 " |
| 10 | 25 | Scotch | Brown | 82 " | .... | L. | 5 hours | 2 | 6 " 10 " | 11 " 3 " | 83 " |
| 53 | 19 | Irish | Red | 88 " | ½ R. | ½ L. | 2 " | 1 | 7 " 8 " | 13 " 5 " | 88 " |
| 27 | 28 | German | Lt. b'wn | 89 " | ½ R. | ½ L. | ½ hour | 1 | ..... | ..... | 90 " |
| 52 | 25 | Swedish | Light | 90 " | ½ R. | ½ L. | 2 hours | 1 | 7 " 5 " | 11 " 3 " | 92 " |
| 55 | 27 | German | Brown | 93 " | ½ R. | ½ L. | 3 " | 1 | 5 " 8 " | ..... | Still-born. |
| 25 | 20 | Irish | Brown | 115 " | .... | L. | 2 " | 1 | 7 " 8 " | ..... | 116 days. |
| 19 | 23 | Irish | Dk. b'wn | 128 " | ½ R. | ½ L. | 1 hour | 1 | 7 " 8 " | 13 " 11 " | 128 " |
| 54 | 19 | German | Dk. b'wn | 132 " | ½ R. | ½ L. | 2 hours | 1 | 8 " 13 " | 14 " 7 " | 132 " |
| 43 | 30 | American | Brown | 150 " | ½ R. | ½ L. | 2 " | 3 | 7 " 14 " | 13 " 4½ " | 150 " |
| 42 | 20 | Irish | Brown | 167 " | ½ R. | ½ L. | 2 " | 1 | 6 " 13½ " | 13 " 12½ " | 167 " |
| 22 | 33 | Swedish | Brown | 180 " | ½ R. | ½ L. | ½ hour | 1 | ..... | ..... | Dead. |
| 44 | 25 | American | Light | 180 " | ½ R. | ½ L. | 2 hours | 3 | 7 " 12 " | 22 " 7 " | 182 days. |
| 46 | 24 | Mulatto | Black | 186 " | ½ R. | ½ L. | 2 " | 2 | 5 " 13 " | 15 " 4½ " | 186 " |
| 50 | 21 | American | Lt. b'wn | 217 " | ½ R. | ½ L. | 2 " | 1 | ..... | 15 " 3 " | 218 " |
| 49 | 19 | Irish | Lt. b'wn | 270 " | ½ R. | ½ L. | 2 " | 1 | 6 " 13 " | 16 " 9½ " | 273 " |
| 60 | 25 | Scotch | Lt. b'wn | 21 " | ½ R. | ½ L. | 5 min. | 1 | ..... | 5 " 8 " | 21 " |
| 61 | 28 | German | Brown | 12 " | ½ R. | ½ L. | 5 " | 2 | ..... | 7 " 10 " | 13 " |
| 62 | 30 | Irish | Black | 27 " | ½ R. | ½ L. | 5 " | 1 | 7 " 8 " | ..... | 29 " |
| 63 | 22 | Irish | Lt. b'wn | 19 " | ½ R. | ½ L. | 5 " | 1 | ..... | 8 " 3 " | 21 " |
| 56 | .. | French | Dk. b'wn | 210 " | R. | .... | 1 hour | 5 | ..... | 18 " 0 " | 210 " |
| 57 | .. | Irish | Brown | 90 " | R. | .... | 2 hours | 1 | ..... | 13 " 10 " | 90 " |
| 58 | .. | Irish | Dk. b'wn | 153 " | ½ R. | ½ L. | 2 " | 1 | ..... | 14 " 2 " | 153 " |
| 59 | .. | Irish | Lt. b'wn | 92 " | R. | .... | 2 " | 3 | ..... | 13 " 4 " | 92 " |
| 36 | .. | ..... | ..... | Descriptions lost. | | | | | | | |
| 37 | .. | | | | | | | | | | |

TABLE II.—ANALYSES OF 80 SAMPLES OF HUMAN MILK.

| Number on blank. | Laboratory number | Color. | Spec. grav. | Albuminoids. | Milk-sugar. | Fat. | Solids not fat. | Ash. | Total solids by addition of constituents. | Total solids directly by evaporation. | Difference. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1021 | Yellow | 1.0321 | 1.44 | 7.20 | 5.58 | 8.81 | 0.17 | 14 39 | 14.46 | —0.07 |
| 2 | 1022 | ..... | 1.0351 | 1.68 | 7.53 | 3.55 | 9.42 | 0.21 | 12 97 | 12.84 | +0.07 |
| 3 | 1023 | White | 1.0353 | 1.96 | 7.31 | 4.62 | 9.45 | 0.18 | 14.07 | 13.96 | +0.11 |
| 4 | 1024 | ..... | 1.0346 | 1.73 | 7.25 | 2.95 | 9.19 | 0.18 | 12.11 | 11.96 | +0.15 |
| 5 | 1025 | White | 1.030 | 1.49 | 7.23 | 2.12 | 8.90 | 0.18 | 11.02 | 11.11 | —0.09 |
| 6 | 1026 | Yw.-white | 1.030 | 1.45 | 7.24 | 3.20 | 8.93 | 0.24 | 12.13 | 12.10 | +0.03 |
| 7 | 1027 | Yellow | 1.034 | 3.12 | 6 47 | 5.49 | 9.91 | 0.32 | 15.40 | 15.35 | +0 05 |
| 8 | 1028 | Yellow | 1.030 | 2.15 | 6.51 | 2.31 | 8 94 | 0.28 | 11.25 | 11.40 | —0.15 |
| 9 | 1029 | ..... | 1.032 | 2.05 | 7.08 | 3.00 | 9.26 | 0.13 | 12.26 | 12.31 | —0.05 |
| 10 | 1030 | ..... | 1.030 | 1.43 | 7.19 | 2.11 | 8 81 | 0.19 | 10.92 | 10.91 | +0.01 |
| 11 | 1031 | ..... | 1.031 | 1.98 | 6 99 | 3.06 | 9.17 | 0 20 | 12.23 | 12.21 | +0 02 |
| 12 | 1032 | ..... | 1.031 | 1.76 | 6.97 | 2.44 | 8.93 | 0.20 | 11.37 | 11.40 | —0.03 |
| 13 | 1033 | ..... | 1.030 | 2.40 | 6.45 | 6 01 | 9.07 | 0 22 | 15.08 | 15.07 | +0.01 |
| 14 | 1034 | ..... | 1.032 | 2.52 | 6.44 | 4.95 | 9.23 | 0.27 | 14 16 | 14.16 | +0.02 |
| 15 | 1035 | ..... | 1.032 | 2.18 | 6.75 | 2.84 | 9.06 | 0 13 | 11.90 | 11.88 | +0 02 |
| 16 | 1036 | Yellow | 1.030 | 0.85 | 5.50 | 6.16 | 6.57 | 0.22 | 12.73 | 12.73 | 0.00 |
| 17 | 1037 | Yellow | 1.034 | 1.49 | 7.37 | 5.02 | 9 03 | 0 17 | 14.05 | 14.18 | —0.13 |
| 18 | 1038 | Dull-white | 1.033 | 3.95 | 7.92 | 4.37 | 12 09 | 0.22 | 16.46 | 16.55 | —0.09 |
| 19 | 1039 | ..... | .... | .... | .... | .... | .... | 0.15 | ..... | 12.34 | .... |
| 20 | 1040 | ..... | .... | .... | .... | .... | .... | 0.30 | ..... | 14 06 | .... |
| 21 | 1041 | ..... | .... | .... | .... | .... | .... | 0.22 | ..... | 13.01 | .... |
| 22 | 1042 | ..... | .... | .... | .... | .... | .... | 0.21 | ..... | 12.74 | .... |
| 23 | 1043 | ..... | 1.030 | 2.10 | 6.61 | 4.02 | 8.91 | 0.20 | 12.93 | 12.88 | +0.05 |
| 24 | 1044 | ..... | 1 030 | 1.94 | 7.45 | 3.61 | 9.56 | 0.16 | 13 17 | 13.02 | +0.15 |
| 25 | 1045 | .... . | 1.032 | 2.16 | 7.00 | 5.84 | 9.38 | 0.22 | 15.22 | 15.18 | +0.04 |
| 26 | 1046 | ..... | 1.030 | 2.08 | 6.98 | 3.28 | 9.26 | 0.20 | 12.54 | 12.39 | +0.15 |
| 27 | 1047 | ..... | 1.031 | 1.98 | 7.00 | 2.44 | 9.19 | 0.21 | 11.63 | 11.84 | —0.21 |
| 28 | 1048 | White | 1 031 | 2.23 | 7.39 | 2.95 | 9.83 | 0.21 | 12.78 | 12 95 | —0.17 |
| 29 | 1049 | White | 1.030 | 1 81 | 6.88 | 2.80 | 8.89 | 0.20 | 11.89 | 11.90 | —0.01 |
| 30 | 1050 | Yw.-white | 1.031 | 2.11 | 7.41 | 5.04 | 9.72 | 0.20 | 14.76 | 14.69 | +0.07 |
| 31 | 1051 | Chalky-white | 1.033 | 2.27 | 6.75 | 5.96 | 9.17 | 0.16 | 15.13 | 15.21 | —0.08 |
| 32 | 1052 | Yw.-white | 1.030 | 1.53 | 5.84 | 5.62 | 7.21 | 0.14 | 12.83 | 12.99 | —0.16 |
| 33 | 1053 | Yellow | 1.030 | 2.24 | 6.25 | 2.76 | 8.84 | 0.35 | 11.60 | 11.45 | +0.15 |
| 34 | 1054 | Chalky white | 1.034 | 2.19 | 7.46 | 6.89 | 9.90 | 0.25 | 16.79 | 16.66 | +0.13 |
| 35 | 1056 | White | 1.032 | 2.43 | 7.34 | 3.13 | 9.98 | 0.21 | 13.11 | 13.20 | —0 09 |
| 36 | 1057 | Yellow | 1.031 | 2.43 | 7.23 | 3.79 | 9.58 | 0.22 | 13.67 | 13.63 | +0 04 |
| 37 | 1058 | Chalky-white | 1.032 | 1.60 | 7.55 | 6.21 | 9.37 | 0.22 | 15 58 | 15.45 | +0.13 |
| 38 | 1064 | White | 1.021 | 1.82 | 6.96 | 3.97 | 8.97 | 0.19 | 12.94 | 12.87 | +0 07 |
| 39 | 1065 | Yw.-white | 1.040 | 2.33 | 5.78 | 4.21 | 8.32 | 0.21 | 12.53 | 12.57 | —0 04 |
| 40 | 1066 | Yellow | 1.032 | 1.75 | 6 94 | 3.68 | 8.97 | 0.28 | 12.65 | 12.52 | +0.13 |
| 41 | 1067 | White | 1.031 | 2.45 | 6.08 | 3.82 | 8.72 | 0.19 | 12.54 | 12.41 | +0 13 |
| 42 | 1055 | White | 1.031 | 1.97 | 7.38 | 4.16 | 9.60 | 0.25 | 13.76 | 13.60 | +0.16 |
| 43 | 1059 | Chalky-white | 1.031 | 1.50 | 7.32 | 3.77 | 9.00 | 0.18 | 12.77 | 12.64 | +0.13 |
| 44 | 1060 | White | 1.030 | 1.49 | 7.31 | 4.34 | 9 01 | 0.21 | 13.35 | 13.17 | +0.18 |
| 45 | 1061 | Yw.-white | 1.031 | 2.33 | 7.48 | 2.47 | 9.97 | 0.16 | 12.44 | 12.38 | +0.06 |
| 46 | 1062 | White | 1.031 | 1.35 | 7.24 | 4.09 | 8.89 | 0.31 | 12.98 | 13.15 | —0.17 |
| 47 | 1063 | Yellow | 1.032 | 4.86 | 5.40 | 3 36 | 9.46 | 0.20 | 13.82 | 13 35 | +0 47 |
| 48 | 1068 | Yw.-white | 1.032 | 1.93 | 6.95 | 5.59 | 9.06 | 0.18 | 14 65 | 14.58 | +0.07 |
| 49 | 1069 | White | 1.031 | 2.00 | 6.95 | 4.64 | 9.16 | 0.21 | 13.80 | 13.74 | +0.06 |
| 50 | 1070 | White | 1.031 | 2.06 | 6.39 | 4.75 | 8.62 | 0.22 | 13.44 | 13.48 | —0.04 |
| 51 | 1071 | Yellow | 1.030 | 2.42 | 6.95 | 5.60 | 9.56 | 0.19 | 15.16 | 15.25 | —0.09 |
| 52 | 1072 | White | 1.031 | 2.15 | 6.76 | 6.78 | 9.07 | 0.16 | 15.85 | 15.89 | —0.04 |
| 53 | 1073 | White | 1.029 | 1.82 | 6.63 | 4.28 | 9.02 | 0.37 | 13.30 | 13.30 | 0.00 |
| 54 | 1074 | Yw.-white | 1.030 | 1 50 | 7.34 | 3.10 | 8.92 | 0.18 | 12.02 | 12.12 | —0.10 |
| 55 | 1075 | White | 1.026 | 2.43 | 6.57 | 4.94 | 9.27 | 0.27 | 14.21 | 14 20 | +0.01 |
| 56–59 | 1133 | ..... | 1.0297 | 1.16 | 7.41 | 4.74 | 8.78 | 0.21 | 13.57 | 13.63 | —0.06 |
| 60–63 | 1134 | ..... | 1.0298 | 1.95 | 7 02 | 3 85 | 9.19 | 0.22 | 13.04 | 13.12 | —0.08 |
| 64 | 1135 | ..... | 1.0312 | 2.00 | 6.69 | 3 96 | 9.01 | 0.32 | 12.97 | 13.05 | —0.08 |
| 65 | 1137 | ..... | 1.0310 | 2.25 | 7.12 | 5 85 | 9.52 | 0.15 | 15.37 | 15.35 | +0.02 |
| 66 | 1138 | ..... | 1.0307 | 1.11 | 7.07 | 2.73 | 8.40 | 0.22 | 11.13 | 11.13 | 0.00 |
| 67 | 1139 | ..... | 1.0322 | 1.96 | 7.28 | 4.74 | 9.54 | 0 30 | 14.28 | 14.28 | 0.00 |
| 68 | 1140 | ..... | 1.0317 | 2.17 | 7.44 | 4.36 | 9.90 | 0.29 | 14 26 | 14.26 | 0.00 |
| Robust | 6 cases | ..... | 1.031 | 1.44 | 6.94 | 3.71 | 8.63 | 0.25 | 12.34 | 12.37 | —0.03 |
| Anæmic | 6 cases | ..... | 1.031 | 2.12 | 6.74 | 3 96 | 9.02 | 0.22 | 13.10 | 13.08 | +0.02 |
| Maximum | | ..... | 1.0353 | 4 86 | 7.92 | 6 89 | 12.09 | 0.37 | 16.79 | 16 66 | 0.21 |
| Minimum | | ..... | 1.0280 | 0.85 | 5.40 | 2.11 | 6.57 | 0.13 | 10.92 | 10.91 | 0 00 |
| Average | | ,,,,,, | 1.0313 | 1.995 | 6.936 | 4.181 | 9.137 | 0.201 | 13.268 | 13.267 | 0.001 |

COMPARISON OF FINAL RESULTS WITH PREVIOUS ANALYSES.

*Analyses of Eighty Samples of Woman's Milk.*

| | Reaction uniformly alkaline. | | |
|---|---|---|---|
| | Average. | Minimum. | Maximum. |
| I. Specific gravity | 1.0313 | 1.0260 | 1.0353 |
| II. Albuminoids | 1.995 | 0.85 | 4.86 |
| III. Sugar | 6.936 | 5.40 | 7.92 |
| IV. Fat | 4.131 | 2.11 | 6.89 |
| V. Solids not fat | 9.137 | 6.57 | 12.09 |
| VI. Ash | 0.201 | 0.13 | 0.37 |
| VII. Total solids (by addition of constituents) | 13.268 | 10.92 | 16.79 |
| VIII. Total solids (directly by evaporation) | 13.267 | 10.91 | 16.66 |
| IX. Difference between VII and VIII. | 0.001 | 0.00 | 0.21 |
| X. Water | 86.732 | 83.21 | 89.08 |

The most interesting comparison which can be made is that with the results given by König (*Chemie der Mensch. Nahrungs und Genussmittel*), which are deduced from the analyses of 190 samples. These analyses, it should be remembered, were performed according to the most diverse methods, errors in opposite directions operating to mutually compensate one another.

Analyses of samples of woman's milk (König):—

| | Average. | Maximum. | Minimum. |
|---|---|---|---|
| Albuminoids | 1.94 | 0.57 | 4.25 |
| Sugar | 6.04 | 4.11 | 7.80 |
| Fat | 3.90 | 1.71 | 7.60 |
| Ash | 0.49 | 0.14 | 1.78 (?) |
| Water | 87.09 | 83.69 | 90.90 |

As might be anticipated, the extremes are wider apart than in my own analyses, but the general mean of all, with exception of the ash, is tolerably concordant.

Omitting particular reference to the results of Vernois and Becquerel and earlier investigations, I will quote further only the results of Gerber (mean of six analyses), Christenn and Marchand (*Beilstein's Handb. der Organ. Chem.*, 2081).

| | Gerber. | Christenn. | Marchand. |
|---|---|---|---|
| Albuminoids | 1.8 | 1.9 | 1.7 |
| Sugar | 5.4 | 6.0 | 7.1 |
| Fat | 5.3 | 4.3 | 3.7 |
| Solids not fat | 7.3 | 8.2 | 9.0 |
| Ash | 0.4 | 0.3 | 0.2 |
| Total solids by evaporation | 10.9 | 12.8 | 12.7 |
| Water | 89.1 | 87.2 | 87.3 |

Biedert (*loc. cit.*) found the albuminoids to vary, in the samples which he analyzed, between 1.5 to 2.4 per cent.; fat, between 3.8 to 4.4 per cent. His mean for albuminoids is 1.95; my own is 1.995; König's is 1.94 per cent.

*Two per cent*, therefore, may be regarded, without sensible error, as *the average amount of albuminoids in woman's milk.*

The more extended series of eighty analyses confirm, however, the statements made in my earlier paper (that on Infant Foods), the albuminoids being the most variable constituent of woman's milk, the fat the next most variable, and the sugar least. Nor have I any reason to alter the interpretation therein given of the physiological signification of the greater and less variability of the individual constituents.

## Relations between the Physical History of the Milk and its Composition.

Relations between the physical history of the milk and its composition.

The only relations which I shall attempt to discuss here are those appertaining to

1. Color, taste, consistency, and specific gravity.
2. Age of the mother.
3. Period of lactation, and interval since nursing.
4. Nationality.
5. Physical constitution of the mother.

1. *Color, Taste, etc.*—Whether bluish-white, chalky-white, whitish, yellowish-white, or yellow, the color is no indication of the composition. For example, the milk of a German brunette, taken one hour after previous nursing and during the tenth day of lactation, was chalky-white in color, whilst it contained 6.89 per cent of fat. This was the largest percentage of fat in any sample. On the other hand, though many of the yellow samples were rich in fat, other yellow samples were very poor. Thus, No. 8 was yellow (the milk being drawn during the fourth day of lactation, and four and one half hours after nursing) while it contained only 2.41 per cent of fat.

*Sugar.*—Although the amount of sugar in woman's milk is large, being nearly 7 per cent or 8 per cent more than in cow's milk, it

is rarely sweet to the taste. Usually, it has a more or less saline, somewhat disagreeable animal flavor.

*Consistency.*—Although the amount of solids in woman's milk is decidedly greater than in cows' milk, its consistency is much thinner and more watery.

*Specific Gravity.*—The average is somewhat greater than in cows' milk, though the entire range of variation is not very different. Thus, in the 80 samples examined, the average specific gravity is 1.0313, the minimum 1.026, the maximum 1.0353. Conrad obtained in 130 observations for the two last figures 1.025 and 1.039. In 147 samples of normal cows' milk L. Janke found 1.0245 for the minimum, 1.034 for the maximum, and 1.0297 for the mean.

II. *Age of Mother.*—The milk of women under the age of 20 is richer in each and every constituent than that of older women, The general average of *albuminoids* for the first lustrum is 2.18 per cent, while it is only 1.92 per cent for the second, and 2.10

TABLE III.—MILK OF WOMEN FROM 15 TO 20 YEARS OF AGE.

(First lustrum.)

A = No. of cases above or below the general average.
B = Averages for A.
C = Averages for women from 15 to 20 years of age.
D = General averages for all years.

| No. of sample. | Albuminoids. | | Milk sugar. | | Fat. | | Solids not fat. | | Ash. | | Total solids. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Above av. | Below av. | Above av. | Below av. | Ab. av. | Bel. av. | Above av. | Below av. | Above av. | Below av. | Above av. | Below av. |
| 7 | 3.12 | ..... | ..... | 6.47 | 5.49 | ..... | 9.91 | ..... | 0.32 | ..... | 15.35 | |
| 18 | 3.95 | ..... | 7.92 | ..... | 4.37 | ..... | 12.09 | ..... | 0.22 | ..... | 16.55 | |
| 28 | 2.23 | ..... | 7.39 | ..... | ..... | 2.95 | 9.83 | ..... | 0.21 | ..... | ..... | 12.95 |
| 35 | 2.43 | ..... | 7.34 | ..... | ..... | 3.13 | 9.98 | ..... | 0.21 | ..... | ..... | 13.20 |
| 21 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 13.01 |
| 51 | 2.42 | ..... | 6.95 | ..... | 5.60 | ..... | 9.56 | ..... | ..... | 0.19 | 15.25 | |
| 3 | ..... | 1.96 | 7.31 | ..... | 4.62 | ..... | 9.45 | ..... | ..... | 0.18 | 13.96 | |
| 1 | ..... | 1.44 | 7.20 | ..... | 5.58 | ..... | ..... | 8.81 | ..... | 0.17 | 14.46 | |
| 17 | ..... | 1.49 | 7.37 | ..... | 5.02 | ..... | ..... | 9.03 | ..... | 0.17 | 14.18 | |
| 11 | ..... | 1.98 | 6.99 | ..... | ..... | 3.06 | 9.17 | ..... | ..... | 0.20 | ..... | 12.21 |
| 53 | ..... | 1.82 | ..... | 6.83 | 4.28 | ..... | ..... | 9.02 | 0.37 | ..... | 13.30 | |
| 54 | ..... | 1.50 | 7.34 | ..... | ..... | 3.10 | ..... | 8.92 | ..... | 0.18 | ..... | 12.12 |
| 49 | 2.00 | ..... | 6.95 | ..... | 4.64 | ..... | 9.16 | ..... | 0.21 | ..... | 13.74 | |
| A | VI. | VI. | X. | II. | VIII | IV. | VIII. | IV. | VI. | VI. | VIII. | V. |
| B | 2.70 | 1.69 | 7.27 | 6.65 | 4.95 | 3.06 | 9.89 | 8.94 | 0.26 | 0.18 | 14.60 | 12.29 |
| C | 2.18 | | 7.17 | | 4.32 | | 9.58 | | 0.22 | | 13.87 | |
| D | 1.995 | | 6.936 | | 4.131 | | 9.137 | | 0.201 | | 13.267 | |

for the third. The difference is still more striking in regard to sugar. In the first lustrum the sugar is 7.17 per cent, falling to 6.91 in the second lustrum, and in the third only 6.77 per cent. This falling off is notable, not only in the percentages, but in the number of samples which exceed the average. Thus, in the first lustrum, 83 per cent. of the whole number of samples exceed the general average in sugar, while in the second lustrum only 60 per cent exceed. A similar diminution is observable in the fat and total solids.

TABLE IV.—MILK OF WOMEN FROM 20 TO 25 YEARS OF AGE.

(Second lustrum.)

A = No. of cases above or below the general average.
B = Averages for A.
C = Averages for women from 20 to 25 years of age.

| No. of sample. | Albuminoids. | | Milk-sugar. | | Fat. | | Solids not fat. | | Ash. | | Total solids. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Above av. | Below av. | Above av. | Below av. | Ab. av. | Bel. av. | Above av. | Below av. | Above av. | Below av. | Above av. | Below av. |
| 38 | ..... | 1.82 | 6.96 | ..... | ..... | 3.97 | ..... | 8.97 | ..... | 0.19 | ..... | 12.87 |
| 15 | 2.18 | ..... | ..... | 6.75 | ..... | 2.84 | ..... | 9.06 | ..... | 0.13 | ..... | 11.88 |
| 16 | ..... | 0.85 | ..... | 5.50 | 6.10 | ..... | ..... | 6.57 | 0.22 | ..... | ..... | 12.73 |
| 29 | ..... | 1.81 | ..... | 6.88 | ..... | 2.80 | ..... | 8.89 | ..... | 0.20 | ..... | 11.70 |
| 30 | 2.11 | ..... | 7.41 | ..... | 5.04 | ..... | 9.72 | ..... | ..... | 0.20 | 14.69 | |
| 40 | ..... | 1.75 | ..... | 6.94 | ..... | 3.68 | ..... | 8.97 | 0.28 | ..... | ..... | 12.52 |
| 64 | 2.00 | ..... | ..... | 6.69 | ..... | 3.96 | ..... | 9.01 | 0.32 | ..... | 13.05 | |
| 45 | 2.33 | ..... | 7.48 | ..... | ..... | 2.47 | 9.97 | ..... | ..... | 0.16 | ..... | 12.36 |
| 43 | ..... | 1.50 | 7.32 | ..... | ..... | 3.77 | ..... | 9.00 | ..... | 0.18 | ..... | 12.64 |
| 34 | 2.19 | ..... | 7.46 | ..... | 6.89 | ..... | 9.90 | ..... | 0.25 | ..... | 16.66 | |
| 33 | 2.24 | ..... | ..... | 6.25 | ..... | 2.76 | ..... | 8.84 | 0.35 | ..... | ..... | 11.45 |
| 4 | ..... | 1.73 | 7.25 | ..... | ..... | 2.95 | 9.19 | ..... | ..... | 0.18 | ..... | 11.96 |
| 39 | 2.33 | ..... | ..... | 5.78 | 4.21 | ..... | ..... | 8.32 | 0.21 | ..... | ..... | 12.57 |
| 48 | ..... | 1.93 | 6.95 | ..... | 5.59 | ..... | ..... | 9.06 | ..... | 0.18 | 14.58 | |
| 31 | 2.27 | ..... | ..... | 6.75 | 5.96 | ..... | 9.17 | ..... | ..... | 0.15 | 15.21 | |
| 68 | 2.17 | ..... | 7.44 | ..... | 4.36 | ..... | 9.90 | ..... | 0.29 | ..... | 14.26 | |
| 5 | ..... | 1.49 | 7.23 | ..... | ..... | 2.12 | ..... | 8.90 | ..... | 0.18 | ..... | 11.11 |
| 2 | ..... | 1.68 | 7.53 | ..... | ..... | 3.55 | 9.42 | ..... | 0.21 | ..... | ..... | 12.84 |
| 12 | ..... | 1.76 | 6.97 | ..... | ..... | 2.44 | ..... | 8.93 | ..... | 0.20 | ..... | 11.40 |
| 25 | 2.16 | ..... | 7.00 | ..... | 5.84 | ..... | 9.38 | ..... | 0.22 | ..... | 15.18 | |
| 42 | ..... | 1.97 | 7.38 | ..... | 4.16 | ..... | 9.60 | ..... | 0.25 | ..... | 13.60 | |
| 33 | 2.24 | ..... | ..... | 6.25 | ..... | 2.76 | ..... | 8.84 | 0.35 | ..... | ..... | 11.45 |
| 46 | ..... | 1.35 | 7.24 | ..... | ..... | 4.09 | ..... | 8.89 | 0.30 | ..... | ..... | 13.15 |
| 50 | 2.06 | ..... | ..... | 6.39 | 4.75 | ..... | ..... | 8.67 | 0.22 | ..... | 13.48 | |
| 26 | 2.08 | ..... | ..... | ..... | ..... | 3.28 | | | | | | |
| 19 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.15 | ..... | 12.34 |
| A | XIII. | XII. | XIV. | X. | X. | XV. | IX. | XV. | XIII. | XII. | IX. | XVI. |
| B | 2.18 | 1.64 | 7.26 | 6.41 | 5.40 | 3.16 | 9.58 | 8.80 | 0.27 | 0.17 | 14.52 | 12.18 |
| C | 1.92 | | 6.91 | | 4.05 | | 9.09 | | 0.22 | | 13.02 | |

TABLE V.—MILK OF WOMEN FROM 25 TO 30 YEARS OF AGE.

(Third lustrum.)

A = No. of cases above or below the general average.
B = Averages for A.
C = Averages for women from 25 to 30 years of age.
D = General averages for all ages.

| No. of sample. | Albuminoids. | | Milk-sugar. | | Fat. | | Solids not fat. | | Ash. | | Total solids. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Above av. | Below av. | Above av. | Below av. | Ab. av. | Bel. av. | Above av. | Below av | Above av. | Below av. | Above av. | Below av. |
| 13 | 2.40 | ..... | ..... | 6.45 | 6.01 | ..... | ..... | 9.07 | 0.22 | ..... | 15.07 | |
| 14 | 2.52 | ..... | ..... | 6.44 | 4.95 | ..... | 9.23 | ..... | 0.27 | ..... | 14.16 | |
| 47 | 4.86 | ..... | ..... | 5.40 | ..... | 3.36 | 9.46 | ..... | ..... | 0.20 | 13.35 | |
| 8 | 2.15 | ..... | ..... | 6.51 | ..... | 2.31 | ..... | 8.94 | 0.28 | ..... | ..... | 11.40 |
| 67 | ..... | 1.96 | 7.28 | ..... | 4.74 | ..... | 9.54 | ..... | 0.30 | ..... | 14.28 | |
| 32 | ..... | 1.53 | ..... | 5.84 | 5.62 | ..... | ..... | 7.21 | ..... | 0.14 | ..... | 12.99 |
| 24 | ..... | 1.94 | 7.45 | ..... | ..... | 3.61 | 9.56 | ..... | ..... | 0.16 | ..... | 13.02 |
| 9 | 2.05 | ..... | 7.08 | ..... | ..... | 3.00 | 9.26 | ..... | ..... | 0.13 | ..... | 12.31 |
| 66 | ..... | 1.11 | 7.07 | ..... | ..... | 2.73 | ..... | 8.40 | 0.22 | ..... | ..... | 11.13 |
| 23 | 2.10 | ..... | ..... | 6.61 | ..... | 4.02 | ..... | 8.91 | ..... | 0.20 | ..... | 12.88 |
| 10 | ..... | 1.45 | 7.19 | ..... | ..... | 2.11 | ..... | 8.81 | ..... | 0.19 | ..... | 10.91 |
| 27 | 1.98 | ..... | 7.00 | ..... | ..... | 2.44 | 9.19 | ..... | 0.21 | ..... | ..... | 11.84 |
| 52 | 2.15 | ..... | ..... | 6.76 | 6.78 | ..... | ..... | 9.07 | ..... | 0.16 | 15.89 | |
| 55 | 2.43 | ..... | ..... | 6.57 | 4.94 | ..... | 9.27 | ..... | 0.27 | ..... | 14.20 | |
| 43 | ..... | 1.50 | 7.32 | ..... | ..... | 3.77 | ..... | 9.00 | ..... | 0.18 | ..... | 12.64 |
| 44 | ..... | 1.49 | 7.31 | ..... | 4.34 | ..... | ..... | 9.01 | 0.21 | ..... | ..... | 13.17 |
| A | VIII. | VIII. | VIII. | VIII. | VII. | IX. | VII. | IX. | VIII. | VIII. | VI. | X. |
| B | 2.58 | 1.62 | 7.21 | 6.32 | 5.34 | 3.04 | 9.36 | 8.71 | 0.25 | 0.17 | 14.49 | 12.23 |
| C | 2.10 | | 6.77 | | 4.04 | | 9.00 | | 0.21 | | 13.08 | |
| D | 1.995 | | 6.936 | | 4.131 | | 9.137 | | 0.201 | | 13.267 | |

This research affords no adequate data as to the rate of decrease beyond the age of 30 years. The only complete analysis bearing upon this point is that of the milk of a dark-haired, black-eyed swarthy Pole, of gross habit and enormous breast development, who, at the age of 33 years, had been the mother of nine children. Two ounces were drawn from the right breast only, five hours after previous nursing. It was low in specific gravity, and yellow in color. It contained:—

| | Per cent. |
|---|---|
| Albuminoids | 2.24 |
| Sugar | 6.25 |
| Fat | 2.76 |
| Solids not fat | 8.84 |
| Ash | 0.35 |
| Total solids | 11.45 |

*Ash.*—Ignite the residue first over a small flame, and finally at a dull-red heat. Cover the dish, cool in the desiccator, and weigh.

*Albuminoids.*—Dissolve 63.5 grms. pure sulphate of copper in a liter of water. Prepare also a potash solution containing 50 grms. caustic potash in 1 liter.

Weigh out 10 grms. of milk in a covered beaker glass, and dilute with 100 c.c. water. Add 2.5 to 3 c.c. of the copper solution. Then run in sufficient potash to exactly neutralize the excess of sulphate, which will require about 1.25 to 1.5 c.c of the potash. The coagulated albuminoids settle immediately, leaving the liquid clear. In testing the reaction, the stirring-rod which has been washed and withdrawn from the solution as soon as the potash has been stirred in, is dipped into the clear supernatant liquid. A drop of this liquid should turn neutral test-paper neither blue nor red. Care should be exercised not to allow the stirring-rod to bring up particles of the coagulum, since these interfere with the reaction. The clear liquid is then decanted through a filter-paper, previously dried at 110°, and weighed in a weighing-flask. The precipitate is then stirred up with 100 c.c. water, allowed to settle, the supernatant liquid again decanted through the filter, and, finally, the precipitate is washed upon it. The beaker is thoroughly cleansed with a rubber washer, and all these filtrates, amounting to about 240 c.c., are finally made up to exactly 250 c.c. for the determination of milk-sugar.

The filter paper containing the precipitate is then opened out upon a large watch-glass, and, after drying to a certain point, is divided up into small particles by a platinum spatula, and this comminution is repeated from time to time until finally the whole mass becomes a fine powder.

*Fat.*—The filter paper containing the precipitate is gathered up and placed loosely in a proper funnel. The beaker-glass used for the precipitation is washed out with ether to dissolve any traces of fat adhering to it, and these ethereal washings are poured through the funnel and allowed to run into a small weighed flask, with which the funnel is connected by a ground-glass joint. The funnel is then connected with a return cooler, the flask carefully heated by a water-bath, and the filter paper is made to swim in the ether condensed in the funnel for about an hour, when the extraction of fat will be complete. The ether is distilled off, the

flask dried at a temperature of 105°, cooled in a desiccator, and weighed. Its increment in weight gives the amount of fat.

*Albuminoids.*—The residue in the filter is dried at 110°, and weighed in the weighing flask until constant weight is attained. It is then ignited in a platinum crucible, and the weight of ash deducted. The loss of weight is the amount of albuminoids.

*Milk Sugar.*—This is determined in the filtrate by Fehling's solution. The figures thus obtained are identical with those found by evaporation of the filtrate to dryness, igniting, and subtracting ash.

In case the above method is carefully followed, the sum of the several constituents as separately determined will not differ by an appreciable quantity from the amount of solid matter as determined directly by evaporation. Thus, it will be seen from the accompanying table, giving the results of 62 separate analyses of human milk (excluding Laboratory No. 1063 as being manifestly affected by some accidental error), the maximum difference is 0.21 per cent.

The average error, as determined by ordinary arithmetical methods, is 0.001 per cent. The probable error of any individual analysis, as determined by the method of least squares, is a difference of 0.0098 per cent. in the sum of the several constituents as found by addition, and the sum as determined by direct evaporation.

This close agreement does not itself prove the accuracy of the methods employed, but, in connection with the fact that an analysis of the fat showed no trace of albuminoids or sugar, that an analysis of the albuminoids revealed no sugar or fat, and that an analysis of the sugar showed no albuminoids or fat, it does afford such proof.

The only serious objection to the method is that, in the precipitation of the albuminoids by Ritthausen's solution, hydrated basic sulphate of copper is precipitated at the same time, and that this hydrate does not lose its water at the temperature at which drying of the albuminates is effected. Hence, the weight obtained would be in excess of the true amount. This objection is not borne out by the results of analyses of the precipitated cupric albuminate, since I have failed to detect in it the presence of more than traces of hydrated basic sulphate.

III. *Period of Lactation, etc.*—If we divide this period into four intervals, the first extending from the beginning of lactation to the eleventh day after; the second from the eleventh to the thirty-first day; the third from the thirty-first to the ninety-first day; the fourth from the ninety-first day to the tenth month of lactation, we shall note the following changes:—

Albuminoids are greatest in the first interval, being 2.32 per cent. In the second, they exceed the general average, being 2.09 per cent. In the third interval they fall as much below the average as in the first they exceeded it, remaining at a low figure during the rest of lactation.

Sugar is least immediately after parturition and much below the average, whilst it is above and nearly constant during the three remaining periods.

TABLE VI.—MILK OF WOMEN FROM FIRST TO ELEVENTH DAY OF LACTATION.

A = No. of cases above or below the general average.
B = Averages for A.
C = Averages from the first to eleventh day of lactation.
D = General averages from the 1st to 270th day of lactation.

| No. of sample. | Day. | Albuminoids | | Milk-sugar. | | Fat. | | Solids not fat. | | Ash. | | Total solids. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Above av. | Below av. |
| 13 | 1 | 2 40 | ..... | ..... | 6.45 | 6.01 | ..... | ..... | 9.07 | 0.22 | ..... | 15.07 | |
| 14 | 1 | 2.52 | ..... | ..... | 6.44 | 4.95 | ..... | 9.23 | ..... | 0.27 | ..... | 14.16 | |
| 7 | 2 | 3.12 | ..... | ..... | 6.47 | 5.49 | ..... | 9.91 | ..... | 0.32 | ..... | 15.35 | |
| 47 | 2 | 4.86 | ..... | ..... | 5.40 | ..... | 3.36 | 9.46 | ..... | ..... | 0.20 | 13.35 | |
| 6 | 2 | ..... | 1.45 | 7.24 | ..... | ..... | 3.20 | ..... | 8.93 | 0.24 | ..... | ..... | 12.10 |
| 38 | 2 | ..... | 1.82 | 6.96 | ..... | ..... | 3.97 | ..... | 8.97 | ..... | 0.19 | ..... | 12.87 |
| 15 | 3 | 2.18 | ..... | ..... | 6.75 | ..... | 2.84 | ..... | 9.06 | ..... | 0.13 | ..... | 11.88 |
| 40 | 3 | ..... | 1.75 | ..... | 6.94 | ..... | 3.68 | ..... | 8.97 | 0.28 | ..... | ..... | 12.52 |
| 64 | 3 | 2.00 | ..... | ..... | 6.69 | ..... | 3.96 | ..... | 9.01 | 0.32 | ..... | 13.05 | |
| 8 | 4 | 2.15 | ..... | ..... | 6.51 | ..... | 2.31 | ..... | 8.94 | 0.28 | ..... | ..... | 11.40 |
| 16 | 5 | ..... | 0.85 | ..... | 5.50 | 6.16 | ..... | ..... | 6.57 | 0.22 | ..... | ..... | 12.73 |
| 45 | 5 | 2.33 | ..... | 7.48 | ..... | ..... | 2.47 | 9.97 | ..... | ..... | 0.16 | ..... | 12.36 |
| 67 | 5 | ..... | 1.96 | 7.28 | ..... | 4.74 | ..... | 9.54 | ..... | 0.30 | ..... | 14.28 | |
| 18 | 6 | 3.95 | ..... | 7.92 | ..... | 4.37 | ..... | 12.09 | ..... | 0.22 | ..... | 16.55 | |
| 41 | 6 | 2.45 | ..... | ..... | 6.08 | ..... | 3.82 | ..... | 8.72 | ..... | 0.19 | ..... | 12.41 |
| 21 | 8 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 13.01 |
| 32 | 10 | ..... | 1.53 | ..... | 5.84 | 5.62 | ..... | ..... | 7.21 | ..... | 0.14 | ..... | 12.99 |
| 34 | 10 | 2.19 | ..... | 7.46 | ..... | 6.89 | ..... | 9.90 | ..... | 0.25 | ..... | 16.66 | |
| A | | XI. | VI. | VI. | XI. | VIII. | IX. | VII. | X. | XI. | VI. | VIII. | X. |
| B | | 2.74 | 1.56 | 7.40 | 6.28 | 5.53 | 3.29 | 10.01 | 8.54 | 0.26 | 0.17 | 14.81 | 12.43 |
| C | | 2.32 | | 6.67 | | 4.93 | | 9.15 | | 0.23 | | 13.48 | |
| D | | 1.995 | | 6.936 | | 4.131 | | 9.137 | | 0.201 | | 13.267 | |

Fat, like the albuminoids, is much in excess of the general average immediately after parturition, being 4.93 per cent. After the eleventh day it falls, being only 3.97 per cent.

The saline constituents are nearly constant during all stages of lactation, although slightly in excess during the first ten days.

The sum of solids not including fat does not vary greatly. Its amount in the first interval is 9.15 per cent, the general average being 9.14.

*Interval since Nursing.*—Nearly all the samples were drawn two hours after nursing, but certain ones, more especially Nos. 18, 32, 33, 39, were drawn immediately. In fat, albuminoids, salts, and total solids, they were in excess of the general average.

TABLE VII.—MILK OF WOMEN FROM THE 11TH TO 31ST DAY OF LACTATION.

| No. of sample. | Day. | Albuminoids | | Milk-sugar. | | Fat. | | Solids not fat. | | Ash. | | Total solids. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Above av. | Below av. |
| 33 | 11 | 2.24 | ..... | ..... | 6.25 | ..... | 2.76 | ..... | 8.84 | 0.35 | ..... | ..... | 11.45 |
| 65 | 12 | 2.25 | ..... | 7.12 | ..... | 5.85 | ..... | 9.52 | ..... | ..... | 0.15 | 15.35 | |
| 26 | 13 | 2.08 | ..... | 6.98 | ..... | ..... | 3.28 | 9.26 | ..... | ..... | 0.20 | ..... | 12.39 |
| 4 | 13 | ..... | 1.73 | 7.25 | ..... | ..... | 2.95 | 9.19 | ..... | ..... | 0.18 | ..... | 11.96 |
| 39 | 13 | 2.33 | ..... | ..... | 5.78 | 4.21 | ..... | ..... | 8.32 | 0.21 | ..... | ..... | 12.57 |
| 29 | 17 | ..... | 1.81 | ..... | 6.88 | ..... | 2.80 | ..... | 8.89 | ..... | 0.20 | 14.69 | |
| 48 | 17 | ..... | 1.93 | ..... | ..... | 5.59 | ..... | ..... | 9.06 | ..... | 0.18 | 14.58 | |
| 28 | 19 | 2.23 | ..... | 7.39 | ..... | ..... | 2.95 | 9.83 | ..... | 0.21 | ..... | ..... | 12.95 |
| 31 | 19 | 2.27 | ..... | ..... | 6.75 | 5.96 | ..... | 9.17 | ..... | ..... | 0.15 | 15.21 | |
| 24 | 20 | ..... | 1.94 | 7.45 | ..... | ..... | 3.61 | 9.56 | ..... | ..... | 0.16 | ..... | 13.02 |
| 9 | 22 | 2.05 | ..... | 7.08 | ..... | ..... | 3.00 | 9.26 | ..... | ..... | 0.13 | ..... | 12.31 |
| 51 | 23 | 2.42 | ..... | 6.95 | ..... | 5.60 | ..... | 9.56 | ..... | ..... | 0.19 | 15.25 | |
| 68 | 23 | 2.17 | ..... | 7.44 | ..... | 4.36 | ..... | 9.90 | ..... | 0.29 | ..... | 14.26 | |
| 8 | 25 | ..... | 1.96 | 7.31 | ..... | 4.62 | ..... | 9.45 | ..... | ..... | 0.18 | 13.96 | |
| 5 | 26 | ..... | 1.49 | 7.23 | ..... | ..... | 2.12 | ..... | 8.90 | ..... | 0.18 | ..... | 11.11 |
| 60-3 | 26 | ..... | 1.95 | 7.02 | ..... | ..... | 3.85 | 9.19 | ..... | 0.22 | ..... | ..... | 13.12 |
| 2 | 27 | ..... | 1.68 | 7.53 | ..... | ..... | 3.55 | 9.42 | ..... | 0.21 | ..... | ..... | 12.84 |
| 30 | 27 | 2.11 | ..... | 7.41 | ..... | 5.04 | ..... | 9.72 | ..... | ..... | 0.20 | 14.69 | |
| 35 | 29 | 2.43 | ..... | 7.34 | ..... | ..... | 3.13 | 9.98 | ..... | 0.21 | ..... | ..... | 13.20 |
| 66 | 30 | ..... | 1.11 | 7.07 | ..... | ..... | 2.73 | ..... | 8.40 | 0.22 | ..... | ..... | 11.13 |
| A | | XI. | IX. | XVI. | IV. | VIII. | XII. | XIV. | VI. | VIII. | XII. | VIII. | XII. |
| B | | 2.23 | 1.76 | 7.22 | 6.42 | 5.02 | 3.23 | 9.50 | 8.74 | 0.24 | 0.17 | 14.75 | 12.25 |
| C | | 2.09 | | 7.06 | | 4.00 | | 9.27 | | 0.201 | | 13.25 | |
| D | | 1.995 | | 6.936 | | 4.131 | | 9.137 | | 0.201 | | 13.267 | |

TABLE VIII.—MILK OF WOMEN FROM THE 31ST TO 91ST DAY OF LACTATION.

| No. of sample. | Day. | Albuminoids | | Milk-sugar. | | Fat. | | Solids not fat. | | Ash. | | Total solids. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Above av. | Below av. |
| 12 | 41 | ..... | 1.76 | 6.97 | ..... | ..... | 2.44 | ..... | 8.93 | ..... | 0.20 | ..... | 11.40 |
| 1 | 45 | ..... | 1.44 | 7.20 | ..... | 5.58 | ..... | ..... | 8.81 | ..... | 0.17 | 14.46 | ..... |
| 17 | 49 | ..... | 1.49 | 7.37 | ..... | 5.02 | ..... | ..... | 9.03 | ..... | 0.17 | 14.18 | ..... |
| 11 | 18 | ..... | 1.98 | 6.99 | ..... | ..... | 3.06 | 9.17 | ..... | ..... | 0.20 | ..... | 12.21 |
| 20 | 50 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.30 | ..... | 14.08 | ..... |
| 28 | 53 | 2.10 | ..... | ..... | 6.61 | ..... | 4.02 | ..... | 8.91 | ..... | 0.20 | ..... | 12.88 |
| 10 | 82 | ..... | 1.45 | 7.19 | ..... | ..... | 2.11 | ..... | 8.81 | ..... | 0.19 | ..... | 10.91 |
| 53 | 88 | ..... | 1.82 | ..... | 6.83 | 4.28 | ..... | ..... | 9.02 | 0.37 | ..... | 13.30 | ..... |
| 27 | 89 | 1.98 | ..... | 7.00 | ..... | ..... | 2.44 | 9.19 | ..... | 0.21 | ..... | ..... | 11.84 |
| 52 | 90 | 2.15 | ..... | ..... | 6.76 | 6.78 | ..... | ..... | 9.07 | ..... | 0.16 | 15.89 | ..... |
| A | | III. | VI. | VI. | III. | IV. | V. | II. | VII. | III. | VII. | V. | V. |
| B | | 2.07 | 1.66 | 7.12 | 6.73 | 5.41 | 2.81 | 9.18 | 8.94 | 0.29 | 0.18 | 14.38 | 11.85 |
| C | | 1.60 | | 6.99 | | 3.97 | | 8.99 | | 0.23 | | 13.11 | |
| D | | 1.995 | | 6.936 | | 4.131 | | 9.137 | | 0.201 | | 13.267 | |

TABLE IX.—MILK OF WOMEN FROM THE 91ST DAY TO THE 10TH MONTH OF LACTATION.

| No. of sample. | Day. | Albuminoids | | Milk-sugar. | | Fat. | | Solids not fat. | | Ash. | | Total solids. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Ab'ye av. | Bel'w av. | Above av. | Below av. |
| 55 | 93 | 2.43 | ..... | ..... | 6.57 | 4.94 | ..... | 9.27 | ..... | 0.27 | ..... | 14.20 | |
| 25 | 115 | 2.16 | ..... | 7.00 | ..... | 5.84 | ..... | 9.38 | ..... | 0.22 | ..... | 15.18 | |
| 19 | 126 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.15 | ..... | 12.34 |
| 54 | 132 | ..... | 1.50 | 7.34 | ..... | ..... | 3.10 | ..... | 8.92 | ..... | 0.18 | ..... | 12.12 |
| 56–9 | 136 | ..... | 1.16 | 7.41 | ..... | 4.79 | ..... | ..... | 8.78 | 0.21 | ..... | 13.63 | |
| 43 | 150 | ..... | 1.50 | 7.32 | ..... | ..... | 3.77 | ..... | 9.00 | ..... | 0.18 | ..... | 12.64 |
| 42 | 167 | ..... | 1.97 | 7.38 | ..... | 4.16 | ..... | 9.60 | ..... | 0.25 | ..... | 13.60 | |
| 22 | 180 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.21 | ..... | ..... | 12.74 |
| 44 | 180 | ..... | 1.49 | 7.31 | ..... | 4.34 | ..... | ..... | 9.01 | 0.21 | ..... | ..... | 13.17 |
| 46 | 186 | ..... | 1.35 | 7.24 | ..... | ..... | 4.09 | ..... | 8.89 | 0.30 | ..... | ..... | 13.15 |
| 50 | 217 | 2.06 | ..... | ..... | 6.39 | 4.75 | ..... | ..... | 8.67 | 0.22 | ..... | 13.48 | |
| 49 | 270 | 2.00 | ..... | 6.95 | ..... | 4.64 | ..... | 9.16 | ..... | 0.21 | ..... | 13.74 | |
| A | | IV. | VI. | VIII. | II. | VII. | III. | IV. | VI. | IX. | III. | VI. | VI. |
| B | | 2.16 | 1.50 | 7.24 | 6.48 | 4.78 | 3.65 | 9.35 | 8.88 | 0.23 | 0.17 | 13.97 | 12.69 |
| C | | 1.78 | | 7.09 | | 4.44 | | 9.07 | | 0.22 | | 13.34 | |
| D | | 1.995 | | 6.936 | | 4.131 | | 9.137 | | 0.201 | | 13.267 | |

IV. *Nationality.*—The statistics are entirely too meagre to determine the influence of nationality. It would be necessary to obtain for each race a large collection of results, in which the other causes of variation, like age, period of lactation, etc., were allowed

for or eliminated. This has never been done, and would require, not eighty, but many hundred, analyses.

The difficulty of generalization upon these points can be most forcibly illustrated by comparing the analysis of sample No. 40, which was obtained from a negress, with the other samples, and with the general average. Neither in color, smell, nor other physical characteristics, nor in chemical constitution, was this one sample so markedly different from the others as to be put, as some have proposed to do with the milk of negro women, in a class by itself.

V. *Physical Constitution of the Mother.*—A comparison of the physical characteristics of the mother, whether blonde or brunette, or more minutely, as to color of eyes, hair, complexion, etc., has not shown that these differences are necessarily related to corresponding differences in the composition of the milk. But actual differences in the physical condition of the mother are intimately related. The samples obtained from women of over-robust habit were not so rich in albuminoids as those from pronouncedly anæmic women; and, generally speaking, the best milk was obtained from lean women in good physical condition.

*Graphic Chart.*—A great deal of labor was devoted to the preparation of a graphic chart of the results of the analyses performed during the course of the present investigation. It was thought that the study of such a chart might reveal some law governing the relative amounts of the various constituents, which law might escape notice in comparing merely tabulated figures. The chart represents the results grouped according to the period of lactation, and follows the same order as that of Table I. In case, however, a number of samples were obtained from the same mother on different dates, these analyses are represented consecutively. These exceptions to the general order of arrangements are to be noted in samples 7, 18, 28, and 35, in samples 15, 16, 26, 29, and 30, and in samples 1 and 17. The horizontal lines in the chart represent differences of one-fifth of one per cent; the vertical columns represent the sample analyzed.

One feature the chart exhibits in the most striking manner, and that is the great variability in the constitution of women's milk. The proportion of fat more especially varies in an exceedingly arbitrary manner. But as to any fixed and definite relation governing the proportion of the constituents to each other, or to the sum total of the solid constituents, the graphic chart thus far has failed to afford a satisfactory indication.

## TITLES OF OTHER PAPERS READ IN SECTION C.

MODIFICATIONS OF RUFFLE'S METHOD FOR THE ABSOLUTE DETERMINATION OF NITROGEN. By Prof. H. C. WHITE, University of Georgia, Athens, Georgia.

ON THE ASSIMILATION OF ATMOSPHERIC NITROGEN BY PLANTS. By Prof. W. O. ATWATER, Wesleyan University, Middletown, Conn.

NOTES ON REINSCH'S TEST. By Dr. HENRY LEFFMANN, Philadelphia, Pa.

APPARATUS FOR THE DETERMINATION OF NITROGEN BY THE COPPER OXIDE METHOD. By Dr. CHARLES W. DABNEY, jr., Director of the N. C. Agricultural Experiment Station, Raleigh, N. C.

A CONVENIENT APPARATUS FOR DETERMINING NITROGEN IN DUPLICATE. By Dr. CHARLES W. DABNEY, jr., Director of the N. C. Agricultural Experiment Station, Raleigh, N. C.

ANHYDROBENZOAMIDOSALICYLIC ACID. By Dr. CHARLES W. DABNEY, jr., Director of the N. C. Agricultural Experiment Station, Raleigh, N. C.

TORSION BALANCES. By Dr. ALFRED SPRINGER, Cincinnati, Ohio.

DISCUSSION ON FERMENTATION. By Dr. ALFRED SPRINGER, Cincinnati, Ohio.

ON A SUBSTITUTE FOR LITMUS AND SIMPLE PROCESSES FOR ESTIMATING ALKALIES, ACIDS, TEMPORARY HARDNESS OF WATER, ETC. By J. F. HEYES, M. A., Christ College, Brecon, England.

A NEW FORM OF GAS REGULATOR. By Prof. F. P. DUNNINGTON, University of Virginia, Va.

SIMPLE LECTURE ILLUSTRATIONS. By Prof. F. P. DUNNINGTON, University of Virginia, Va.

PRODUCTION OF ARGENTIC HYDRATE. By Prof. F. P. DUNNINGTON, University of Virginia, Va.

IMPROVEMENTS IN APPARATUS FOR RAPID GAS ANALYSIS. By Dr. ARTHUR H. ELLIOT, School of Mines, Columbia College, New York, N. Y.

## SECTION D.

# MECHANICAL SCIENCE.

# ADDRESS

BY

## PROFESSOR ROBERT H. THURSTON,

VICE PRESIDENT, SECTION D.

## *THE MISSION OF SCIENCE.*

BEFORE taking up the subject which I have selected as a proper one for discussion in a vice-president's address, on this occasion, I desire to give expression to my sense of the great honor which has been conferred upon me in calling me, for a third time, to the chair of vice-president of the American Association for the Advancement of Science, and to preside at the sessions of the section. In taking the position to which your too favorable judgment has called me, it is my first and most pleasant duty to thank you for this most unequivocal testimony of the confidence which you repose in me, and to assure you of my earnest desire to do what little my opportunities and my powers may permit toward making your sessions both pleasant and profitable, and toward promoting the prosperity of the great association to which we are proud to belong.

We are especially favored, the present year, in having with us members of our great sister society, the British Association for the Advancement of Science, who have come to join us from Montreal, where the meeting of that society has just been held, and where they have taken part in proceedings of no less importance than interest. It is our pleasant duty to tender to these gentlemen a hearty welcome, and to endeavor to make their visit to the "City of Brotherly Love" one that shall leave in their memories so many reminiscences of agreeable acquaintances made, of strong friendships begun, of open-handed and open-hearted hospitalities, and of profitable and interesting discussions, that they may never forget the cognomen of this noble city. If we shall be able to give

deference to the enlightened views of Sir John Cutler, the Chair of Mechanics was founded in the Royal Society of Great Britain. May we not hope that this Section of Mechanics of the American Association for the Advancement of Science may prove to be worthy, in its interest, its fruitfulness, and its stimulation of other and greater work, of so grand an anniversary?

I have selected the subject of my address on this occasion, "The Mission of Science," as one peculiarly appropriate to the time and the occasion.

Seven years ago, at the Nashville meeting, I was called, by the members of what was then Section A of this association, to take the chair, in the absence of the regularly elected vice-president for that meeting, and performed the pleasant task of reading an address, prepared by him, on the "Endowment of Science." Before the meeting of 1878, at St. Louis, in the regular course of my duties as vice-president, and as chairman of the same section, it became necessary to prepare an address to be delivered before the association, and the subject then chosen was "The Philosophic method of Advancement of Science," or, perhaps more explicitly, The Science of the Advancement of Science. In the first of these addresses, the attention of the association was earnestly called to the necessity of increasing the efficiency of scientific work, and of making most fruitful the labor of the comparatively few workers in this field, in the United States, by securing such an endowment of research as is now, fortunately for our nation, becoming usual in the departments of higher education. In the second of these discourses, I endeavored to point out what, in my opinion, is the truly scientific method of securing the greatest possible results with minimum expenditure of life, strength, mind and matter, and at least cost to the world.

I defined science, substantially, as knowledge systematically organized. I then called attention to the facts that it consists of two divisions: knowledge of phenomena gathered by observation and experiment, and knowledge of laws controlling and correlating these phenomena. As then stated, "all science is thus made up from the infinite number of facts which are comprehended in the universe of the known and the to be known. Its existence is assured by the stability of all those principles of philosophy which are woven into the connecting chain." "The man of science, the philosopher whose task it is to create and to advance all human

knowledge of the great kingdom of nature, is, therefore, a discoverer of facts, an observer of phenomena, a student of Nature's laws. He is a systematic recorder of facts, and a codifier of laws." It was shown that all science has for its foundation the great, the fundamental principle of the indestructibility of "the two products of creation, matter and force, and the fruit of their union, energy." The next step in the argument led to the classification of the forces of nature into physical — including chemical — vital, mental, and "the master power, Omnipotence, which is the source and the sustainer of all existences," and this division leads naturally to a similar division of science into physical, biological and mental sciences. It is with the first of these grand divisions of science, only, that we are concerned.

The scientific method of advancing science was shown to comprehend a systematic collection of all facts and phenomena, as exhibited to the senses in the course of our experience, either by simple observation or by carefully conducted experiment; the systematic arrangement of the knowledge so obtained, and the registration of this knowledge in natural order and relations; the study of such recorded facts of science with the purpose of ascertaining the laws that define their relations; the similar coordination of separate collections of such related facts and laws, for the purpose of detecting the character and the mathematical form of the more general laws that may determine the relations of group to group and of science to science; and finally, the aggregation, if it prove to be possible, of all science into one universal system comprehending all the phenomena of nature.

To accomplish this great work there are needed several classes of workers, each of whom, to secure maximum efficiency, must be a specialist, and must give his time and his thought and his strength mainly to a single line of work. We must have observers, each of whom should be fitted by every natural endowment for the study of nature, and for the investigation, by direct experiments intelligently planned and skilfully conducted, of the natural phenomena which are characteristic of, and, perhaps, peculiar to, his branch. We must have philosophers capable of perceiving and expressing the relations of the phenomena so collected, and of thus revealing to us the laws of each of the sciences. We need men who can perceive and exhibit the relations of the several sciences to each other, and their positions in the scheme of universal science. Finally,

we require a still larger and more directly useful class, the teachers of science and the no less important body of laborers who make application of science in all the arts of daily life and work.

But all of these classes being organized, and all the fields of work open to man being assigned to them, each taking his proper division of the great task, progress would be but slow, and, in these days almost at a standstill, but for the aid of still another body of co-laborers, who, without pretending to deep knowledge in any division of science, without possessing talent for research, either in the laboratory or in the study, and unable often to realize all the beauty and all the importance of the mighty work that they are helping on, nevertheless generously devote the fruit of years of toil and the product of enormous activities and energy to the cause. These are those who have given, and who are still generously and liberally giving, material assistance by their splendid contributions to the scientific departments in our colleges and of our technical schools. The endowment of research, which will certainly ere long become an acknowledged and legitimate division of this work, is, after all, as essential an element of the scientific method of advancing science as either of the others. Those who give of their substance to aid in the promotion of science are entitled to hardly less honor than those who devote life and health and strength to the good work. Those who take part in the endowment of research are the truest and greatest of modern philanthropists.

When we have thus ascertained what is the philosophic method of the advancement of science, and have determined how we may most efficiently carry on the work in the true spirit of the "science of science-advancement," we may find it to our advantage to pause, and to ask to what end is all this labor to be applied. What is the object of directing this enormous array of intellectual power into the field of scientific inquiry? Having settled upon the form of the system, and the details of the mechanism by which this development of science is to be secured with greatest ease, accuracy and rapidity, to what purpose is this great scheme to be applied? What is the use, and what is the object, of systematically gathering knowledge and of constructing a great, an elaborate, system having the promotion of science as its sole end and aim? What is "THE MISSION OF SCIENCE?"

The mission of science is the promotion of the welfare, material, and spiritual, physical and intellectual, of the human race. It has

for its purpose and its object the improvement, in every imaginable way, directly and indirectly, of the mind and the body, the heart and the soul, of every human being. It is charged with the duty of seeking the cause of every ill to which mankind is subject; of finding a remedy for every misfortune to which the race is now liable; of ameliorating every misery known to sage or savage; of seeking ways of giving to all every comfort and all healthful luxuries; of reducing the hours of toil, and offering to the relieved laborer intellectual occupations that shall at once take from him all temptation to waste his life in indolence and dissipation and give him aid in his feeble efforts to climb upward into a higher life; of enlightening the world intellectually; of giving it leisure to perfect itself ethically, and to gain those elements of character that are so sadly crushed out by the terrible pressure of our incomplete civilization, sentiments of honor and justice, feelings of love and sympathy, and a spirit of devotion that can only be found highly developed in either the simple child of nature, or in the soul that has time, in the midst of a driving world, to reflect, to aspire and to grow. The true mission of science is one that extends far beyond the workshop of its servants; it extends far beyond our ken, and beyond the range of our mental grasp and farthest view. The great fact that material prosperity is the fruit of science, and that other great truth, that as mankind is given opportunity for meditation and for culture, the higher attributes of human character are given development, are the best indications of the nature of the real mission of science, and of the correctness of the conclusion that the use and the aim of scientific inquiry are to be sought in the region beyond and above the material world to which those studies are confined.

The Mission of Science will be fulfilled in precisely the degree to which it assists us in the protection and preservation of the individual, of the family and of the nation; just so far as it aids each member of the race to attain the allotted term of life, continuous health, and a maximum of happiness, while, at the same time, giving him the opportunity to assist his neighbor most effectively in the endeavor to reach the same ends, and so far as it stimulates him to do well every duty that comes to him whether in his private or his public relations. It will aid every citizen in his efforts to gain the most that can be secured by the practice of industry, skill, intelligence and frugality, to obtain the comfortable inde-

pendence that every man hopes to enjoy in his old age, and the means of carrying his children on to a higher plane than that upon which he himself entered when taking up his life's work.

The methods properly adopted in the endeavor to prosecute this mission, so far as they relate to the development of the sciences, have been already summarized. It has been seen that the method is in itself scientific. Science first observes, then experiments with a view to the revelation of new facts and unknown laws by systematic research, then applies the power of logic to the construction of an organized, complete and exact system of definite knowledge. First she collects facts and records phenomena, then she seeks to discover and exactly to enunciate the laws controlling them, and finally produces, by the intelligent use both of induction and deduction, a symmetrical and perfect whole. Thus she creates systems of knowledge, and thus she will sometime, we may hope, knit these several systems into one great all-embracing system of the universe.

But, while this scientific method of advancement of science is evidently that which will yield the greatest returns, it is not the fact that we are indebted to such philosophic methods for the production of the modern sciences. It is a fact which is more significant than surprising that, as Whewell remarks, "art has always gone in advance and science has followed to give the reasons for the phenomena discovered and the methods found best in art." "Art is the parent, not the progeny, of science," and, while it is true that progress is always most rapid and most satisfactory when art and science go hand in hand, it has been almost invariably the case that art has struggled painfully and haltingly and doubtfully onward, in every department, slowly and unsteadily advancing, yet almost always going before science, who should have been her leader, her teacher, and her most powerful supporter. This fact is not to be considered as representing a natural state of things nor as in the slightest degree discouraging. Like every art, science, in each of its departments, has been passing through a period of infancy, during which it knew neither its powers, its object or mission, nor its proper methods of work. It required protection and the aid of art until it should be fully formed and competent to take up its labors and to requite the assistance which had been given it. In the past the arts have led; in the future we shall see science leading and directing every development of the arts. His-

tory tells us that bleaching and dyeing were familiar arts before the science of chemistry had a name; the inventor of gunpowder lived before Lavoisier; the mariner's compass pointed the seaman to the pole before magnetism took form as a science; the steam-engine was invented and set at work, substantially in all essential details as we know it to-day, before a science of thermo-dynamics was dreamed of; the telegraph and the telephone, the electric light and the railroad, have made us familiar with marvels greater than those of fiction, and yet have been principally developed, in every instance, by men who had acquired less of scientific knowledge than we demand to-day of every college-bred lad.

But all this is of the past. Science has attained a development, a stature and a power, that gives her the ability to assume her place in the great scheme of civilization. Hereafter she will direct and will lead. The blind, scheming ways of the older inventor will give place to the exact determination, by scientific methods, of the most direct and most efficient way of reaching a defined end—methods now daily practised by the engineer in designing his machinery. Instead of long, discouraging, and painful efforts to reach a result which is indistinctly defined, science will, hereafter, first determine just what is the end to be sought, and then will show the direct line to that end. Uncertainty will give place to certainty, and wasted work will be reduced to the least possible amount.

The aids to science have been already briefly referred to. They are partly material, partly moral, partly intellectual. In the very infancy of civilization the most efficient aids were tendered freely to science. The rulers of the earliest historic nations gave encouragement to the sciences, such as they were in their day; governments founded universities in the days of the Greeks and the Romans; the greatest minds of those times were led to turn their attention to philosophy, and students in thousands thronged the schools. Aristotle made a rude yet definite beginning in the physical sciences; Alexander endowed research most liberally in the person of his great master: the same great warrior urged upon Nearchus the prosecution of the greatest of his plans of geographical exploration, and gave him means to carry out his schemes; an enormous library at Alexandria furnished the student the then available knowledge of the world; the enormous "museum" in which it was preserved gave an impetus to science that has never

been lost; Euclid, Archimedes, Eratosthenes, Hipparchus and Hero, those wonderful men who gave us geometry, taught us the elements of mechanics, the principles of hydrostatics and the lever, founded systematic astronomy and physical geography, put on record the earliest notions of the correct form of the earth and the motions of the moon, catalogued the stars, and measured their angular distances, and who first used and described the germ of the steam engine and a thousand other mechanical inventions, were themselves the product of an enlightened policy.

The Arabians transferred the seat of science to the west, and erected her capital near the shore of the Atlantic. Experimental science there had a new birth, and the wealth of the Saracens, and the intellect of the greatest among the Moors and the Jews, there contributed to the growth of real knowledge. Alchemy, the parent of chemistry, was there born, and her progress has never since been interrupted. Marcus Graecus' gunpowder, the more powerful acids, phosphorus, and systematic chemical methods of investigation, are some of the products of the intellectual activity of that time.

Centuries later, and after a period of stagnation and darkness, the light again flashes up and this time it appears in what is now the home of European civilization. The extension of commerce leads to maritime discovery; the awakening of the people by these, to them, startling discoveries, leads to progress in every direction. Galileo and Bruno die that science may forever live; the invention of the telescope stimulates astronomical discovery, and the formation of the modern science of the solar and sidereal systems; the magnificent labors of Newton illustrate the progress of the sciences of physics and mechanics. Every branch of natural philosophy grows and puts forth branches in turn, and the idea of the universal dominion of physical laws becomes accepted as a foundation principle in science, and as the basis of the operations of the universe. Geology, ethnology, physiology, the broader science of biology, take form and grow with astonishing rapidity; and, with their growth, come the minor sciences and the enormous mass of underlying facts determined by the now well-established methods of scientific investigation. Finally, in the later times in which the last three or four generations have borne a part, science and art have learned to work together, and have gone on, hand in hand, each aiding the other, art supplying facts, science finding out

nature's laws as illustrated in those facts, and both, gradually, and more and more rapidly and fully, revealing the beautiful and wonderful system upon which the world is constructed, and all its curious operations carried on, while, at the same time, applying useful knowledge, thus acquired, in promoting the welfare of the human race. Electricity and magnetism, light and heat, and every form of physical energy and of active force, have become revealed to man in all their relations, and in all their methods of operation. Discoveries in physics and chemistry succeed each other with a rapidity that taxes even the specialist who endeavors to keep himself informed in regard to them. Mechanical inventions crowd into our life with such wonder-working results that every day sees a new task accomplished that, the day before, would have been regarded as little less than miraculous. The human voice is transmitted a thousand miles, the written word is sent across the bed of an ocean three thousand miles wide, almost in less time than is required to write it; the traveller breakfasts at Boston, dines at New York, and sups at Washington on the same day. Ten thousand tons are transported from continent to continent, over fifty degrees of longitude, in six days; one workman, with the assistance of machinery, produces more than, a century ago, could a hundred men, doing their best, in the earlier rude ways. We read, in the beam of light, the distance and the rate of motion of the stars, and learn in the same wonderful system of ethereal waves, to determine the nature of the matter of which those stars are composed. Man is turning his work in the world over to the more exact and more powerful machines that he has devised and built, and machinery here weaves his cloths, there gathers his grain, and yonder makes for mankind other machines, doing its work with a strength that is never overtaxed, and an endurance that is never found to reach a limit. Relieved from bodily toil, mankind is coming to that condition of social life in which mental activity absorbs its surplus energies, and the material and intellectual development of civilization are carried on together, and with continually accelerated progress.

This is the history of the past, and this is the picture of the growth of science which we are to study to obtain an idea of what shall be its future. Whenever and wherever the mind has been set free to study and to meditate, to observe and to experiment, science has advanced, and the whole race has felt the benefits of her labors.

This work of science has always demanded the material assistance of acquired wealth, and has given to the investment so made its highest return, its best and most bountiful reward. Whenever and wherever, in the future, science shall have the substantial aid that she needs to secure permanent and convenient quarters, and to prosecute her work, then and there will the progress of mankind be accelerated; and this acceleration will be in proportion to the completeness with which the scientific method of promotion of science is adopted. The characteristics of stationary periods, according to Whewell, are "obscurity of thought, servility, an intolerant disposition, and an enthusiastic temper." Science teaches exactness and clearness of thought and expression, perfect independence of mind, the most absolute tolerance of honestly held and frankly-expressed opinion, and a quiet coolness of action and a deliberation, however enthusiastic may be the nature of the individual, that may be depended upon to yield a correct judgment. The rapidity of recent changes in our methods of work is due very largely to the introduction and extension of these characteristics of the scientific method, and to the influence of the scientific spirit upon mankind.

It is only in modern times, and since the old spirit of contempt for art, and of reverence for the non-utilitarian element in science, has become nearly extinguished, and since our systems of education have begun to include the study of physical science, that we have had what is properly called a division of "Applied Science." In the days of classical learning, science was only valued as it developed a system of purely intellectual gymnastics; the old Socratic spirit still survives, but is fortunately without influence upon our modern life. Socrates rejected and condemned all physical and mathematical science, and, seeking to impart his own contempt for real knowledge to his disciples, urged upon them the study, exclusively, of ethical philosophy, while, at the same time, himself failing to give to his followers a real system of morals. He accused men of science of reaching vain conclusions, while he was himself lost in the labyrinth of his own indefinite and baseless speculations. Plato followed in the same track, developing splendid ideas by uniting the power of a great intellect with the brightness of primitive imagination, and awakening noble sentiments while giving no assistance to his poor fellow-creatures who desired to conquer the necessary leisure for the enjoyment of life. Aristotle

in physics, and Zeno in ethics, employed the scientific method, but their achievements were only appreciated in proportion to their inutility. Archimedes was the most perfect prototype, in those days, of the modern physicist and mechanician, of the scientific man and engineer; yet he, and all of his contemporaries, esteemed his discovery of the relation between the volumes of the cylinder and the sphere more highly than that of the method of determining the specific gravity of a solid or the composition of an alloy, and deemed the quadrature of the parabola a greater achievement than the theory of the lever which might "move the world." His enumeration of the sands of the sea-shore was looked upon as a nobler accomplishment than the invention of the catapult, or of the pump, which, twenty-one centuries after his death, still bears his name.

No system of applied science could exist among people who had no conception of the true mission of science, and it was not until many centuries had passed that mankind reached such a position in their slow progress toward a real civilization, that it became possible to effect that union of science and the arts which is the distinguishing characteristic of the age in which we live. It was not until the middle of the sixteenth century that Copernicus and the modern system of astronomy became possible; Columbus lived but a little earlier; Gilbert, also, a little later, supplied a basis for the science of magnetism; Galileo applied his genius to the production of the telescope. His first use of the invention was to earn martyrdom by its application to the proof of the truth of the Copernican system, one of the most splendid of all the achievements of applied science. The revelation of the phases of Venus was one of the facts which marks the conversion of the world from the old Greek methods of scientific thought. It was not until the middle of the fifteenth century that Europe could produce a Leonardo da Vinci, the first of the great mechanics and engineers of modern times. Taking up the work of applying science where his predecessor, Archimedes, had left it, seventeen centuries before, he accomplished an amount of work in the application of the physical sciences and of the science of mechanics, that few men in later times have been able to approach, and none, probably, to equal. He revealed the theory of the lever, extending the work of Archimedes to the more general case; he was acquainted with the laws of hydraulics, understood the nature and effects of

friction, and, to a certain extent, its laws. Stevinus followed da Vinci, and Galileo's treatise on mechanics, which appeared in 1592, and his "dialogues" of 1633, crystallized the knowledge of his time in accessible and practically available form. Then came Torricelli, and, a little later, that greatest of English philosophers and mechanicians, Newton, whose "Principia" has been, from 1686 to the present time, a mine which has richly repaid all the less illustrious workers who have chosen to explore it. This wonderful geometer gave all his mighty intellectual power to the work of usefully applying science. He enunciated the laws of motion, deduced the law of gravitation, proved, by the application of his cumbersome but fruitful methods, the exactness of Kepler's laws, showed their generality, and pointed out the fact that they hold the planets in their orbits, and sway the whole stellar world.

The time of Newton marks the beginning of a grand outburst of energy in the useful application of the sciences. Every art, every industry, every phase of human life, felt its helping hand. Inventions began to appear, to relieve the delving laborer, in every department of human industry. The arts began to find a scientific basis, and to look to science for aid in their perfection and in their development; the industries began to feel the stimulating effect of scientific discoveries, and of the introduction of scientific methods of application of practical knowledge; Descartes, Newton and Leibnitz advanced mathematics to a point from which only a Hamilton or a Sylvester could carry it further; Lavoisier and his contemporaries, only a century before our own time, created chemistry; geology had its birth almost within the memory of our elder colleagues; the several departments of physics have taken definite shape almost within our own shorter memories; the natural sciences have come into being since the time of Cuvier and Linnæus; the greater science of "energetics" is hardly yet defined, and has not taken its place in the text-books taught in even our schools of science. We are, in fact, at the very threshold of the true era of applied science.

In illustration of the gradual evolution and growth of correct theory, and of this slow development of rational views, of the methods of scientific deduction, and of the invariably tardy progress from a beginning distinguished by defective knowledge and inaccurate logic, in the presence of what are later seen to be plainly visible facts, and of what ultimately seem obvious principles,

observe the rise and progress of our hardly-yet completed theory of that greatest of human inventions—the steam-engine.

Studying the history of the development of this theory, it cannot fail to become strikingly evident that, throughout, experimental knowledge and practical construction have been constantly in advance of the theory, and that the science of the conversion of heat-energy into mechanical power has, in all stages of this progress, come in simply to confirm general conclusions previously reached by deduction from experience and observation, to give the reasons for well-ascertained facts and phenomena, and often—not always promptly or exactly—to define the line of improvements, and the limitations of such advance.

The theory itself began by the correlation of the facts determined by the experiments of Rumford and Davy, at the bèginning of the century, those announced by Joule and Thompson many years later, and the laws developed by Clausius, Rankine, and Thompson, at the middle of the century. But Watt had discovered the facts which have since been found to set limits to the efficiency of the engine, a hundred years ago; Smeaton, in many respects, the greatest mechanical engineer of his time, made practically useful application of the knowledge so acquired, and endeavored to secure immunity from these wastes by thoroughly philosophical methods. Clark, a generation ago, showed how the losses first detected by Watt set a definite limit, under the conditions of familiar practice, to the gain to be secured by the expansion of steam; and Cotterill within a few years has shown, by beautiful methods of treatment, their magnitnde, and how these wastes take place. Hirn and Leloutre, in France, have thrown additional light upon the phenomena of "cylinder condensation," and De Freminville has suggested the method of remedy. Yet it is only now that we are beginning to see that the philosophy of heat-engines is not simply a thermo-dynamic theory, and that it involves problems in physics, and a study of the methods of conduction and transfer of heat, without doing work, from point to point in the engine. We are only now learning how to apply to knowledge gained by Isherwood twenty years ago, and by Hirn and by Clark still earlier, in solving the problem of maximum efficiency of the steam-engine. We have only now discovered that the "curve of efficiency," as I have taken the liberty of calling it, is not the curve of mean pressure for "adiabatic" expansion, as Rankine called it—for

"isentropic" expansion, as Clausius would call it—but that it is a curve of very different form and location, and that it is variable with every physical condition affecting the working of the expanding fluid in the engine. We have only now learned that every heat-engine has a certain "ratio of expansion for maximum efficiency," which marks the limit to gain in economy by expansion, which limit is fixed for each engine by the nature of the expansion, and the method and extent of wastes of heat. All the facts of this case were apparently as obvious, as easily detected and weighed in their influence upon the theory of heat-engines, years ago, as to-day. Even the latest phase of the current discussion of efficiencies of heat-engines, that relating to their commercial efficiency, would seem to have been as ready for development a generation ago, when first noted by Rankine, as to-day; yet, what is now known as a simple and easily formulated theory has been several decades in growing into shape, notwithstanding that all the needed facts were known, or readily determinable, at the very beginning of the period marked by its evolution. It is only within a year or two that it has become possible to say that the theory of the steam-engine, as a case in applied mechanics, has become so complete that the engineer can safely rest upon it in the preparation of his designs, and in his calculations of power, economy, and commercial efficiency.

Even in the lowest department of applied mechanics, that which forms the basis of the work of the engineer—that including the study of the materials of construction—our knowledge, scientific or general, has been wonderfully slow of development. Experimental work may be said to have commenced in this field a century ago, and the labors of Muschenbroech, of Tredgold, of Barlow and of Hodgkinson, of Fairbairn, and of their coadjutors of the first half of the century, gave to the constructor and to the theorist the facts which were most essential to their work. But it is only within the past few years that the conditions modifying the value of these materials, as applied in engineering, have been carefully and critically studied by the light of experimental investigation. The effect of heat upon strength and elasticity; the alteration of structure produced by vibration; the difference in carrying power and in safe loading, due to reversed stresses; the modification of the value of steel by alteration of chemical composition and by various modes of tempering; the effect of that

singular phenomenon, the variation of the normal line of elastic limits by strain; the persistence of the effect of strain in the production of cold-worked iron and steel, and in the permanent record of the results of accidents straining structures,—all these have been matters left for the present generation to investigate.

It is only to-day that we are beginning to ascertain the existence of alloys and special modifications of iron and steel which adapt these metals to special purposes, and the engineer is only now becoming accustomed to the writing of specifications including details of the composition and character of the materials to be used in his work. The use of manganese steels and bronzes, of the phosphor bronzes, and of various other deoxidized alloys, the search for the exact location of the alloy of maximum possible value for specified purposes; the continuation of researches in regard to the effect of prolonged loading of materials and of structures; these and similar matters are those which are receiving the attention of the engineer of our day, and are merely the beginnings of a *renaissance* in applied mechanics which is likely to reveal wonders where they have been least expected and most rarely looked for.

But the slow progress of scientific development in matters relating to common practice in the useful arts is hardly less remarkable than the difficulty with which scientific principles, even when well established and well known among scientific and educated men, sink down into the minds of the masses. Perhaps no principle in the whole range of physical science is better established and more generally recognized than that which asserts the maximum efficiency of fluid in heat engines to be a function, simply, of the temperatures of reception and rejection of heat, and to be absolutely independent of the nature of the working fluid. This was shown by Carnot, sixty years ago, and has been considered one of the fundamental principles of thermo-dynamics from that time to this. Nevertheless, so rarely is it comprehended by mechanics, and so difficult is it for the average mind to accept this truth, that the most magnificent fallacies of the time are based upon assumptions in direct contradiction of it. The various new "motors" recently brought before the public with the claim of more than possible perfection, have taken hundreds of thousands of dollars, within the past two or three years, from the pockets of credulous and greedy victims. It is not sufficient to declare the principle; the comparison of steam with ether, and of air or gas

with carbon-disulphide or chloroform, must be made directly, and the results presented in exact figures, before the unfortunate investor—whose rapaciousness is too often such as to cause him to give ear to the swindler, rather than to the well-informed and disinterested professional to whom he would ordinarily at once go for advice—can be induced to withdraw from the dangerous but seductive scheme. It is true that the principle does not as exactly apply to a comparison of efficiencies of machine, and that the vendor of new motors usually seizes upon this point as his vantage ground; but a careful comparison of the several fluids, both as to efficiency of fluid and efficiency of machine, throughout the whole range of temperatures and pressures found practicable in application, such as has recently been made under my direction, shows that the final deduction is substantially the same for all the usually attainable conditions of practice, and, further, that of all the available fluids, steam is, fortunately, the best.

It is only since our political body became a nation that the application of scientific methods of experiment led that great engineer, James Watt, to the invention of the greatest of mechanical civilizing agents, the modern steam-engine. It is within the life-span of many who are still living that the art of spinning, the art of weaving by machinery, the production of the cotton gin, the invention of the sewing machine, and a thousand other now familiar and essential factors of our present life, have been born of this union of science and art. The locomotive, the steamship, the telegraph the telephone, are all younger members of the same family—the mighty progeny of that mightier pair. The world has learned to value science for her beneficence, for her fruitfulness, for her helpfulness. It has learned that to a true union of science with art only, are we to look for the methods and the means by which mankind is to be finally, if at all, emancipated from the yoke of overburdening labor now so terribly oppressing the race.

The cultivation of science, in its relations to every branch of the arts, and to every department of the industries of the world; the collection of practically important facts, and the discovery of its essential laws, as forming a system of application of science, is, as is now sufficiently evident, the task which lies before every scientific worker. It is further evident that there must be inaugurated a *system* of cultivation of science that shall promote the advancement of scientific knowledge, and that shall aid in the

application of science to the daily work of humanity. We have seen what such a system must be, and how it must be developed and set in operation. In the carrying out of this system of promotion and cultivation of science, we are to see that men of science are given all necessary assistance in their noble task; and the way in which this aid is to be obtained and made effective has been already discussed at sufficient length. But, when this part of our work has been satisfactorily organized and set in operation, we have the no less important task left us to see that the knowledge so acquired shall be preserved and communicated to the new generation. This leads us to consider our methods of education.

Glancing back into history, we find that the distinction which I have pointed out between the old and the new schools of philosophy and of thought has been equally marked in the methods of education of the older civilization and the new. Only a few decades have passed since the only education that could be obtained in our schools was one embracing merely the purely literary and the speculative, with a small allowance of pure mathematics. The languages, history, literature, the elementary mathematics, and the old systems of speculative philosophy, were the principal subjects taught in our colleges. Gradually, the natural and physical sciences came in, and were given a subordinate place in the college course, and then only under protest. The stereotyped argument for the retention of the old system, to the exclusion of the new, was, and is to-day, the assertion that the old system strengthened the intellect and broadened the views of the student, while the new subjects were *merely useful*. The fact that the study of science is the most effective of disciplines for the reasoning faculties, for the memory, for the judgment, and for the very faculties for which the older instruction is claimed to do so much, is not even now perceived, far less admitted, by many of our most distinguished and ablest educators. But in spite of all difficulties arising from ignorance, prejudice, habit and opposing interests, the study of applied sciences is becoming as well established as part of the modern college course, as is that of any branch of pure science; and the study of pure science is very steadily becoming a more important part of the standard system of general education—of "liberal" education—while, at the same time, it is gradually becoming changed in its form of presentation, to adapt it more per-

fectly to its subsequent use in application. Speculation is everywhere losing its place, and investigation and systematic research are advancing to occupy the deserted ground.

The modern method of education is becoming thoroughly systematic. It involves the introduction of scientific methods of promotion of the efficiency of instruction; it includes the careful study of every detail of the educational system, and of the whole course of tuition, determining what methods are the most fruitful of useful and practically valuable results, what are the subjects, and what the methods of presentation, which give to the learner the largest amount of permanently retainable and widely applicable knowledge. Our primary education has always, and necessarily, been distinguished by the predominance of the scientific method and of the practical side. We have not been driven so imperatively toward this use of scientific methods, and of application of the sciences bearing upon common life, in the higher education; but the wisdom and the expediency of a modification of old ways, in this respect, is now rapidly becoming acknowledged, and the new education may be considered as fairly and safely introduced. We may call it the modern systematic method, the scientific method, of education. Science will never, we may be sure, displace entirely the older departments of education; but science will henceforth take a place beside them as no less valuable for mental discipline, and as the essential factor in the promotion of progress in all the arts and employments, in all the daily life and work of the world.

And not only may we feel assured that science will never entirely displace the older systems of education, although certain soon to take her rightful place beside literature and philosophy, with her own most efficient servant, mathematics; but we may plainly see that the time is not far distant when we shall have, for those who propose making science their mistress, and for those who are to make the work of their lives the application of science to the arts and the humbler industries of the world, "schools of science in every city, colleges of science in every State," and universities of science, pure and applied, as the base of the great pyramidal educational system. And it may be anticipated that when the system shall have become perfected and of full growth, it will be the universal custom of those proposing to study in these advanced schools, to secure, first, the general education, the broad culture, and the disciplinary preparatory training, that the aca-

demic schools now give, before entering upon the special branches of study that are to be continued through their later lives.

Students of science will enter these professional schools from the colleges of the country, precisely as they now enter the medical schools and the schools of law, making their professional studies post-graduate courses. The line will thus lie through the primary schools, which are becoming each year better fitted to give the child the best introduction into a life either of labor or of study, through the higher schools, in which instruction is daily becoming more practically valuable, both in the imparting of knowledge and in mental discipline, through the college, where the discipline already given will make the student capable of securing good and permanently valuable knowledge, into the scientific school, and, in many cases, onward and upward into the university of sciences, in which all science is specialized for those who propose, as all scientific men must, to devote themselves wholly to scientific work.

Thus, ultimately, will science lead, direct, and most efficiently aid, the nation in its progress toward the ideal, yet approachable, social state which has been the hoped-for, if not the promised, land of every great political and social economist and philosopher, from the days when Cicero thought it his greatest honor to have written "On the Commonwealth," up to the present time. According to Cicero, the Roman Commonwealth, "by defending its allies," took possession of the world. Our own grander commonwealth, by defending and sustaining her as yet hardly recognized, but most powerful and most beneficent ally, Science, will, sometime, control, and for vastly grander purposes, a greater world.

The place of these modern methods in our political and social system can now be readily determined. Had it been asserted a generation ago that science should control our politics and dictate in every movement of our social system, and that it should be the guiding star of every political economist and of every philosopher, whatever his province, the claim would have excited a smile, and would neither have received consideration nor provoked rejoinder. But we shall see that this is precisely the place which will be ultimately, and of necessity, taken by science, and that it is to science that every great movement, whether political or social, industrial or ethical, must look for intelligent direction.

The object of every correct system of government is to secure to every member of the society which it guards protection of

life and property, liberty to earn as much wealth and to secure as many of the comforts and luxuries of this life as he may, and opportunity to prepare the coming generation most effectively for successfully doing the work that lies before it. This is not the object accomplished by the old governments. They were established for the purpose of promoting the welfare of ruling individuals, or of ruling classes; and the result of their control of society was, invariably, the elevation of the one class at the expense of the other; the rulers flourished at the cost of those who were ruled. Modern systems of government are continually approaching that ideal form in which the people govern the people, and in which the public good and the security of the citizen is the end sought. But, as it is the end and aim of every good government to promote the welfare of the citizen by purely general legislation, and by the enforcement of laws enacted without reference to individuals or classes, it becomes the duty of the citizen who appoints the legislator, and of the legislator who makes the laws, to seek the scientific, the logically and the ethically correct, method of promoting general welfare. It is here that science, at the very start, becomes properly our guide. The government is charged with the duty of guarding and promoting every legitimate industry, of giving every citizen the means of preparing himself to do his work in the world and of developing, in every proper way, the natural resources and the appropriate industries of the territory over which it has control. How this can best be done it is the province of science to point out. Men of science, each in his own department, are the natural advisers of the legislator. Citizens and legislators are both entitled to claim this aid from those who have made the sciences of the several arts their special study, and from those who have devoted their lives to the study of the sciences of government, of social economy, and of ethics.

Of all the many fields in which the men of science of our day are working, that which most nearly concerns us, and that which is of most essential importance to the people of our time, is that department of applied science which is most closely related to the industries of the world. The two great needs of mankind to-day are, first, an education that shall enable the workers to acquire all the necessaries of civilized life, a fair share of the comforts, and even some of its luxuries; second, such provision for the non-workers, deserving but invalid, willing but impotent, as shall insure

them against actual suffering, and, if possible, give them some compensation, in the short remainder of life, for their misfortunes. By thus reducing the suffering existing in the world, science will accomplish its highest mission. Government has two main objects to secure; the suppression of crime and the promotion of industries. It is in the latter that applied science finds its plainest and its most obvious line of application, and in such application, as we shall readily perceive, the department of science which must find widest and most important fields of application will inevitably be that of "Mechanics."

Mechanics directs the advancement of the world in an astonishingly greater degree than does any other department of science, and it has, therefore, correspondingly great importance as one of the great agents of civilization. Every industry is largely mechanical; nearly all of the products of the labor of the world are given form, to a greater or less extent, and usually principally, by mechanism. It is applied mechanics that sows and reaps our grain, that grinds our flour, that transports it to domestic markets, that carries it across the ocean to the half-fed people of Europe; it is applied mechanics that prepares our cotton for the mill, that compresses the product of acres into a bale that may be handled by a single strong man, that spins our cotton and our wool, weaves them into cloth, and even cuts the cloth to pattern, and, by its most ingenious of minor applications, the sewing machine, gives the garment permanent form. Applied mechanics gives to the astronomer his telescope, enables him to calculate the elements of the planets and the stars, teaches the mariner his system of navigation, gives him the ship that he thus directs, guides the engineer in his magnificent work of designing the machinery which impels the enormous structure. Even the sister sciences, physics and chemistry, are departments of applied mechanics, and are coming to take their place in the wide spreading department of "molecular mechanics," and in a still more comprehensive but younger branch of our science—that of "energetics."

Even vital forces are gradually coming to be grouped under the same head, and all the natural sciences are more and more generally recognized as properly falling into the department of energetics, and as illustrations of the application of the laws of mechanics. The Mission of Science is to be fulfilled mainly, then, through the application of mechanics.

How the application of our beautiful and noble science is to promote the welfare of the race by the solution of the apparently abstract problems which everywhere challenge the student of science may not always be readily perceived. The mechanics of the ether, the determination of the exact measurements of its elasticity and density—of which we only know to-day that the one is probably as enormous as the other is inconceivably small—the character of its vibrations, the method of distribution of its molecules, their magnitudes and distances, and the extent of their movements; the methods of conversion of mechanical energy, or of other forms of energy, into light and into heat; the great problem of transformation of heat into mechanical energy without waste; the still greater problem of the direct transmutation of the work of chemical combination into other forms of work and power; the discovery of the nature and method of operation of those forces which give rise to chemical and electrical energy; the method of conversion of the two forms of energy, the one into the other, with maximum efficiency; all these are problems that confront the investigator to-day, and all have, directly or indirectly, although it may not be easily seen just how, a real bearing upon the prosperity of the race. Those more directly "practical" problems, such as the discovery of a means of making non-conducting working cylinders for our heat engines; the production of the electric arc without variation of intensity of light; the development of mechanical power with absolute steadiness and uniformity of speed; the concentration of power for aeronautic applications; the application of the mechanic's inventive power to the cheapening of all the methods of production and supply of the perishable necessaries of life; all these are obviously within the province of our science in the prosecution of its beneficent mission. But it is not enough that it shall be made possible that one pair of hands shall do the work of two; work must be found in new fields for the pair of hands thus thrown out, and this makes it the duty of science and of its workers to see that new departments of skilled employment shall be opened to surplus labor. Thus the development of new industries becomes as much a part of the work of science in the future as is the improvement of those now existing. The new industries must evidently be mainly skilled industries, and must afford employment to the more intelligent and more finely endowed of those to whom our modern systems of education are offering

their best gifts. When this process of industrial revolution shall have been effected, the great mass of mankind will be able to secure by the labor of each day, restricted to such number of working hours as shall best develop and maintain in healthy condition the whole muscular system, all the necessaries and comforts of civilized life, and will yet find time for recreation and for the cultivation of the moral and intellectual faculties, and for the development of all the mental powers and of all the affections.

The progress of science, as seen in her past history, resembles that of the great steamships which are now the embodiment of the most wonderful of the results of human intellect, working through the scientific applications of mechanics, which to-day mark the advanced position of civilization. In the building of the steamer long weeks are spent in the preparation of plans, in the calculation of proportions, and in the determination of the form in which the enormous masses of iron are to be grouped; months are spent in gathering the materials together which are to be given shape in the great vessel, and which are to be turned and planed and cast and forged into the pieces composing the mighty engines and lesser machinery; during months and months the tremendous structure lies motionless upon the ways, slowly taking shape, slowly receiving the massive machinery which is to form the vital apparatus essential to the life-like action of that powerful, and hardly less than living, creature. No sign of life or power is seen during this long period of development, and, to the uninstructed observer, it may appear utterly improbable that the dormant mass can ever be more than an inert, and useless hulk; yet, after a time, when the period of preparation is completed, and when all that is needed for the purposes intended by the designer and the constructor has been brought together and put in place, suitably connected, part to part, there comes a time when a change and a movement are perceived. A few insignificant pieces of timber are knocked away, and the enormous vessel, slowly and by imperceptible acceleration, moves down toward the water, and, with continually increasing speed, finally rushes into the element which is to be, for all its future life, its home. A halt and a little more delay, and a now fully equipped and self-impelling steamship once more moves. Starting again, with slow and hardly visible motion, by the exertion of her own unseen, but inconceivable power, the great ship gradually acquires velocity, and we see her, later, traversing the

ocean, back and forth, over a thousand leagues of water like an enormous shuttle, weaving bands that tie closer and closer hitherto separated members of a common race, of one human stock, and binding the nations daily into more perfect brotherhood.

So it was with science in the past, and so is it in the present. Long ages ago, in the earliest historic period, was her time of slow and unobserved generation and embryonic growth. All through the middle ages signs were not wanting of her existence and gradual development, in the changing methods of thought of mankind, and in the accumulation of materials to be usefully applied at a later date. At the beginning of the seventeenth century, the first great movement began, and then only did the true purpose of all that earlier period of preparation become evident. A century ago, with the birth of the steam-engine, later, with the introduction of product of the printing press into the daily life of the world, with the apparition of the electric telegraph and the introduction of the railroad, began the real progress of science, and we are now seeing but the beginning of her awe-inspiring career. She has taught us to drive ten thousand tons across the seas, regardless of wind and waves, by the might of our 12,000 horse-power engines—engines in which steam does more work than fifty thousand actual horses could do, continuously. She has taught us to send printed messages across the oceans and across the continents, girdling the world with her mysterious wire; she has shown us how to drive the railway train, with its hundreds of tons of merchandise and living freight, faster than birds can fly; she has helped us give to the people news of every land, gathered in every clime, and brought to us by messengers swifter than the shadows of the sun, and printed on millions of sheets between the first glowing of the dawn and the rising of the orb of which Aurora is the messenger; she has given practical expression to a myriad of other hardly less magnificent philanthropies. Yet the mission of science has made but the veriest beginning. It still remains to her to perfect and to systematize a thousand new industries, to invent as yet unimagined new arts, to bring the laborer worthy of his hire all that he needs, and all that he can desire for his own comfort and for the care and comfort of his family, to so adjust the power of production to that of consumption, and both to the working capacity of the world, that the now seeming natural conflict between the employer and the employee, between labor

and capital—that fallacy which is the support of every demagogue —shall no longer have even the appearance of existence. She has still to do her part toward the reduction of all systems of government to the one only correct form; that in which the people are governed by the people, for the best good of the people, and in which legislation is solely directed towards the protection of life, of liberty to do right, toward the protection and support of the industries of the country, the sustaining of a system of education that shall give to every citizen the opportunity to fit himself with maximum efficiency for the duties of a well planned life, and the encouragement in every right and reasonable way, of all that tends to aid the material and the moral welfare of the community.

She has all this and much more to do; and her highest work will be found to include, I think, important modifications of the methods of evolution and of conformation of the race. The enormous advancement of the intellectual side of life must inevitably, as it seems to me, result in the production of a race of men peculiarly adapted to such environment as science is rapidly producing. Thus accomplishing, under the guidance of our science, such tasks as lie before him to accomplish, the "Coming Man," with his greater frontal development, his increased mental and nerve power, his growing endurance and probably lengthening life, will be the greatest of the products of this scientific development, and the noblest of all these wonderful works. And may it not be possible in the better days of that future into which we may now barely get the faintest glimpse, when the increase of the population of the world shall be limited, not as now by the maximum of misery and suffering bearable by the race, nor yet by art, not by a Malthusian system, but by the rate of expenditure of vital power in the operations of the mind, of the intellect and of the affections, when those who are brought into the world shall have fair prospect of being permitted to lead happy and prosperous lives, when suffering and misery shall have been reduced to a minimum—that we may see man taking the place assigned him by Ruskin? Says that great master of expression: "All the power of nature depends upon subjection to the human soul. Man is the sun of the world; more than the real sun. The fire of his wonderful heart is the only light and heat worth gauge or measure. Where he is are the tropics; where he is not, the ice-world." May not this development of the human soul be, after all, the true Mission of Science?

As a toil-worn traveller,wearily faring homeward at early dawn, skirts the western shore of some broad lake, picking his way by the uncertain, but always increasing, light penetrating the cloud beflecked sky, at last sees in the east the uprising sun, and watches its steadily growing disk, and the wide-extended sheaves and pencils of splendent golden light, silvering and gilding, and magnificently tinting, every snowy pile of vapor, etherializing all the low-lying mist that hides the bosom of the lake, and sees finally, across the rippling waves stirred by the first gentle breezes of the dawn, the flashing of a broad band of glory, each wave at the distant shore catching up its share of the wonderful illumination, each its handful of the beautiful light, each passing it onward to the nearer swell, and each catching new beauty from the passing beams of the day-god, until the eyes are dazzled by the spreading sheen, and all the scene is surcharged with light, until the glory covers the weary one, lightening his heart, cheering his soul, quickening his step, and sending him homeward, with all his sadness gone, refreshed, hopeful, and happy,—

So man, plodding onward, sad, overburdened, and despairing, toiling wearily over the shifting sands of life, at last has seen, across the expanse of eternity, along the shores of which he wanders, the first bright beams of the light of Science, heralded, but hidden, through a dawn that had lasted for centuries; and, as the bright luminary that is to guide him through all the future, has arisen, steadily and constantly, among the obscuring, but breaking, clouds of the dark ages, the mists have been dispelled, the clouds themselves have received golden and silver linings, and the all-pervading beams, caught and reflected, but always advancing, have finally reached the hither shore, and man, enlightened and strengthened, with new insight into a brightening life, himself advances, with new courage and renewed hope, toward that future which it is the heaven-directed Mission of Science to illumine with the radiance of ever-increasing knowledge.

# PAPERS READ.

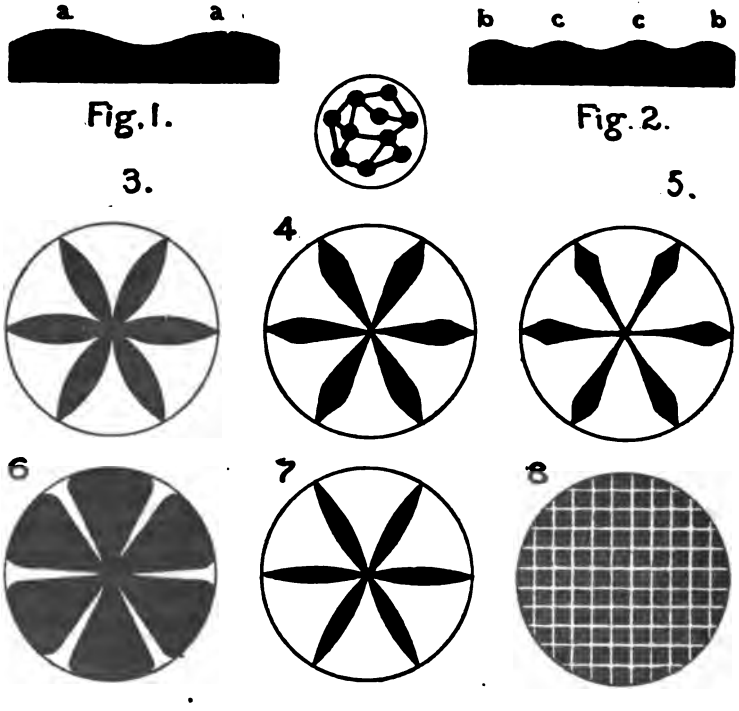
THE PRODUCTION OF OPTICAL SURFACES. By JOHN A. BRASHEAR, Pittsburg, Pa.

IT is the purpose of this paper to describe briefly a new method of producing accurate optical surfaces, both plane and curved. The hand and machine methods of past and present workers in this line of research should not be forgotten, especially Foucault's method of local correction and Dr. Draper's excellent modification thereof.

In order that the new method may be the more clearly understood, attention is called to the serious difficulties met with in producing regular surfaces with the ordinary forms and methods of using local polishers. It is quite well known that the tendency of all local retouching is to leave on the surface of the abraded material what may be aptly called residual errors. This may be readily understood by the following illustration.

Suppose in the sectional view, Fig. 1, we wish to work down the high zone, *a*, in an over corrected surface. A local polisher is worked over the high zone, either by hand or machine, of a size corresponding with the breadth of the zone and usually circular in outline. The result of this local abrasion is seen in Fig. 2 in which the zone, *a*, Fig. 1, is seen to be broken down, but generally the residual zones, *b* and *c*, are left incompletely abraded by the edge of the local polisher, which must afterwards be abraded by a larger polisher, which may or may not introduce new periodic or systematic errors. Dr. Draper seems to have overcome this tendency in a great measure by the use of the machine described in his monograph. After many experiments and much careful study of these zonal errors, I endeavored to eliminate them with a machine constructed so as to give an intricate motion to the polisher, a motion that would scarcely return into itself in many thousands of strokes. Notwithstanding the fact that this machine produced a number of excellent curves, it could not be depended upon,

for in spite of the intricate interlacing of the polisher, zonal errors would creep in. After six years of labor I reluctantly gave up the pursuit in this direction. From the fact that occasionally good results were produced by the machine, I was led to a careful study of the forms of polishers, and after three years of experimental work, I have been led to this conclusion: that, given a properly shaped polisher, surfaces of the highest excellence may be produced; either by hand or machine work, and that the simple ro-




tary and reciprocal motions are all that are necessary to be given to the polishing tool.

I will now give as briefly as possible the leading features of the method which I have found so sure and certain in its results, by which not only zonal errors are overcome, but by which any desired curve may be given to the optical surface under treatment. As it is necessary in all optical work to get the highest attainable polish, the first polishers are made in the ordinary form, *i. e.*, with

square or circular facets equally distributed over the surface of the tool, as shown in Fig. 8. This is done to expedite the polishing. When the polish is brought up to the best (the best polish is no doubt the *finest scratching* we are able to do) the glass is allowed to come to a normal temperature, and is then studied by the admirable methods devised by M. Foucault for curved, and by Steinheil and Dr. C. S. Hastings for flat surfaces. Very seldom are the surfaces found free from defect. In order to clearly understand the method which I use for the correction of errors in producing a *regular* curve, let us take the former case of Fig. 1, where the Foucault test shows a decided over correction or hyperboloid of revolution on the concave surface. The zone *a* is to be depressed and at the same time new errors, especially zonal errors, are to be avoided. The iron tool, which is of the same diameter as the surface to be worked, is laid off into six points diametrically opposite with the dividers set to the radius of the tool; as in Fig. 3. The tool is now warmed and the pitch is spread over the leaf-like spaces, which are given the proper curve by being pressed down on the (previously wetted) concave surface. The pitch and tool are now cooled quickly by an abundant flow of water. In the shaping of this leaflet lies the whole secret of success. The zone, *a*, Fig. 1, needing the greatest amount of abrasion, the leaflet is made widest at that point, but in order that no zonal errors may be introduced, as in Fig. 2, it is gently tapered in each direction, the amount of taper being somewhat governed by the amount of lateral stroke given to the polisher, as well as the amount of departure of the zone from the normal curve. After the proper shape is given to the correcting or figuring tool, the pitch is again slightly warmed, pressed on the wetted surface, laid aside for an hour or so, and the work of correcting or figuring is then begun. When the polisher has worked long enough to transfer its own peculiarities to the surface under treatment, the glass is allowed to come to a normal temperature and again tested. If any change in the shape of the leaflets is needed, an inspection of the surface will indicate the character of the change required.

Cooper Key many years ago graduated the square facets of his polisher. Elliptical, ring and other forms of polishers have been tried from time to time with varying success, and I have myself tried many forms, but with none have I had such uniform success as with the form which I have just described. It has all the ad-

vantages of a local polisher without its defects, and as these leaflets can be so readily shaped, and so easily manipulated, we have a ready means of giving any desired form to the optical surface we are manipulating. Figs. 4, 5 and 6 show the various forms of these polishers which are designed to correct different forms of errors. Fig. 7 shows a polishing or figuring tool which will give fine results, when time is not an element in the work. Such a polisher would break down almost any form of irregular surface, and give a *regular* curve, the kind of curve — oblate spheroid, spherical, elliptical, paraboloid or hyperboloid, depending on the length of lateral motion given to the polisher; indeed almost any idiosyncrasy which a curve may present can be successfully treated with a slight modification of this form of polisher.

Flat surfaces may also be treated by modifications of the same general form of tool, and overworking the edge zone, so difficult to avoid in hand polishing, can be readily and easily overcome.

It is beyond the limits of this paper to discuss the various difficulties which the practical optician has to deal with besides those noted; but I would mention one thing that seems to be an insurmountable barrier to the production of an ideal optical surface, in the lack of homogeneousness in material. It is a fact well known to every one who has to deal with minute measurements that no two pieces of glass, speculum metal or other optical material made by artificial means are ever absolutely homogeneous when they come into the hands of the optician; hence every piece of material must have its special study, and in many cases idiosyncrasies present themselves which say "Thus far shalt thou come, but no farther." If, in this brief paper, I have said anything that will add to the interest of this study, intimately associated with the names of Newton, Herschel, Ross, Lassell, Foucault, Nasmyth, Dr. Draper and many eminent opticians of to-day, I shall feel more than repaid for my work.

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THE GIANT'S CAUSEWAY AND PORTRUSH ELECTRIC TRAMWAY (IRELAND). By WILLIAM A. TRAILL, C. E., Portrush, Co. Antrim, Ireland.

[ABSTRACT.[1]]

THIS road has a finished length of seven miles and a gauge of three feet. It follows the turnpike which skirts the cliffs over-

[1] Abstract made from the full paper by J. Burkitt Webb, Secretary of the Section.

looking the sea, and is built upon a sort of sidewalk raised a few inches above the road and separated from it by a curbstone. Forty-two lb. Bessemer steel flanged rails are used for the most of the line and answer also for the return conductor, the main conductor being a 19-lb. T rail placed at the side of the road about 18 in. above the ground. The alignment is an unfavorable one, having curves with a minimum radius of 42 feet and grades of 1 in 50 and even 1 in 25, and some of the worst curves are on heavy grades. The road rises in places to 185 feet above the sea. At present the cars stop at Bushmills, two miles short of the Causeway and six miles from the town of Portrush. A single track is used, with passing places about a mile apart, and these are always on inclines, so that one car is run by gravity while passing the other. The current is taken from the three-inch-broad top of the T rail by springs, which rub along on it, and as there are numerous openings, generally 10 ft. wide, in this rail, to allow the turnpike travel to pass, each car has two springs far enough apart to reach across such openings. The cars are run by $D_1$ or $D_2$ Siemens motors, running respectively, 850 and 1200 revolutions per minute, and these speeds are reduced by cog wheels and chain gearing connected with the car axles; an average speed of about twelve miles an hour is attained, and a second car is generally drawn behind the electric car. The electricity is generated on the Bush river, three-quarters of a mile from Bushmills, and is carried the whole length of the line with but a slight loss. Two American turbines (Alcott's) of 50 H. P. each are used, one of them, with its gates half to three-quarters open, being sufficient for ordinary traffic. The dynamo used is a $SD_{00}$ Siemens "compound wound" weighing 35 cwt., and furnishing a current up to 100 ampères with a maximum potential of 250 volts. This maximum potential is fixed by law so that no dangerous shock can be received by contact with the rails.

The road was opened in the fall of 1883, and has been in successful operation since that time; thus the Lichterfelde and the Charlottenburg railways, respectively one and a quarter and one and three-quarter miles long, constructed by Siemens Bros. in Berlin, antedate this railway by a year or two. In the first of these the two rails are used for the direct and return current, with much leakage of current; in the second, two conductors are carried along the road on telegraph poles from which connection is

made to the car by a flexible running conductor. The greatest difficulty experienced so far has been in the attempt to regulate the flow of water to the wheel by an automatic governor, the trouble being that the stoppage of a car throws off instantly 80 to 85 per cent of the work from the turbine, so that an immediate corresponding decrease of the water supply must be made; on the contrary, in starting the car the water must be turned on again gradually. When it is added that Sir Wm. Thompson now occupies a position in the board of managers in place of the late Sir William Siemens, it will be seen that the electrical arrangements of this road are and have been in the best of hands. The following details may be of interest. Two loaded cars upon the worst gradient require a current of 60 ampères, the maximum potential being 250 volts. The resistance of conductors from the generating station to Portrush and back is less than 2 ohms, while the resistance of the insulation ("insulite") of the conductors varies from 500 to 1000 ohms, according to the weather. The total leakage along the line may be as much as 2.5 ampères, or $\frac{3}{4}$ H. P.

In eight months after the opening, 13000 "electric-car miles" were run, the daily run in summer being 100 car miles with 600 to 800 passengers. For nearly a year previous to Nov., 1883, steam cars were used on the line so that a reliable comparison between the cost of running by electricity and by steam can be made. The cost of running by steam, including the wages of attendants, coke, oil, etc., was ten cents per mile run, while with electricity this was reduced to less than four, and with such additional traffic as could easily be accommodated with the existing plant it would not be over two and one-half cents. Experience also warrants the prediction that "on a more favorably circumstanced tramway, with a service of single cars, running at short intervals, the working expenses might be reduced to $\frac{1}{2}$ d (one cent) per mile run, and that even though the electricity should have to be generated by steam power." It would seem from an inspection of the detailed expenses of running, that, owing to the higher wages paid here, the comparison, while leaving a large margin in favor of electricity, would not be so overwhelmingly against steam except in localities where abundant water power is available.

The cost of the line has been $150,000, as follows: "parliamentary law, engineering and preliminary, $15,000; construction of six miles of tramway, one mile of branch and sidings, buildings,

carriage and engine sheds, $80,000; water-power generating station turbines, electric conductors and cables, $22,500; electric plant, generating dynamos and motors, $10,000; rolling stock; two tramway engines, nine tramway cars, fourteen wagons and mineral trucks, $22,500." The road is understood now to be not only in successful and continuous working, but in a paying condition, which recommends it to the careful study of those interested in such matters in the United States.

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ELECTRIC TRAMWAYS. By M. HOLROYD SMITH, Fern Hill, Halifax, England.[1]

[ABSTRACT.]

To demonstrate the practicability of Mr. Smith's system of electric tramways an experimental line has been laid in a field near the works of Messrs. Smith, Baker & Co., Manchester, England. The track is 110 yards long and 4′ 8½″ gauge; it is essentially level and the car is driven by the traction of the ordinary wheels, but it contains some sharp curves. On the latter account one wheel on each axle is loose and the power is distributed between the two wheels on the axle by differential bevel gears, so that both wheels drive equally well on curves and straight line. The movable bevel gear in this arrangement is driven by a steel chain from a Siemens motor and the current is brought up from an underground conduit, which forms the main feature of the line. This conduit is constructed in much the same manner as a cable line, with a copper conductor in place of the cable. This copper conductor is double and consists of two half tubes,—as if a tube had been cut in two lengthwise and vertically and the two halves separated somewhat from each other. In this tube, then, a shoe slides, being connected both electrically and by leather straps with the car, the leather straps breaking should the shoe be accidentally obstructed, as by pebbles jammed in the groove. The rubbing part of the shoe, or shuttle, consists of spirally-grooved rollers, whose axis is that of the tube, and whose slow revolution, caused by friction, keeps the tube cleaned out perfectly. The rails answer

[1] Mr. Smith not being present the paper was read by Mr. Preece. Abstract by the Secretary.

for the return current. This method of supplying the electrical current to the cars is so successful, and the conductor is so well protected in the underground channel, that after a week's rain the leakage, if any, was so small that the improved contact of the moist shoe prevented any difference from showing in the speed of the cars.

(It would seem that this system would be specially fitted to replace the cable system so soon as a sufficient economy of power can be shown in its favor.)

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ARE THE ADVANTAGES OF A TRIP GEAR WORTH ITS GREATER COST THAN EXCENTRICS? By ARTHUR RIGG, President of the Society of Engineers, London, England.

[ABSTRACT.]

THIS paper discusses the construction of "trip-gear" regulated engines, as compared with the action of double excentrics. Its conclusions are based upon the idea that the use of such gear limits the revolutions of an engine to a rate considerably below that of any other parts of its construction. Therefore the first cost of such engines is rendered excessive. It is then pointed out that two excentrics can cut off steam through any desired range with a speed sufficiently great for all practical purposes, and the author concludes that any arrangement of valves now worked by trip-gear could be equally well driven by double excentrics with the advantage that the number of revolutions and power of such engines might be considerably increased.

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THE STRENGTH OF CAST IRON. By W. J. MILLAR, C. E., Secretary Institute of Engineers and Shipbuilders, Glasgow, Scotland.

[ABSTRACT.]

(1) *Object of paper:*—Results of tests of strength of cast iron (made in Glasgow).

(2) References to former experiments by the author. These summarized are:—

(3) The test bars used were 40″ long, 2″ deep and 1″ broad. Span 36″, loaded at centre.

(*a*) Deflection varied fairly with load.

(*b*) The "set" *decreased* with successive applications of the same load and even for increased loads;—ultimately disappearing.

(*c*) The fracture when at centre of span was *straight;* when at points more or less removed from centre it was *curved.*

(4) Recent Experiments. Influence of vibratory action on bars and tensile links, from which the author finds that bars and links may be broken by striking with light and continuous blows, even although the load at the time may be considerably below the ultimate load, the deflection and extension increasing with each blow.

(5) The average transverse strength of 30 bars was found to be 3476 lbs., deflection .390 inch. The tensile strength of 15 links of same metal was found to be 11 tons, 11 cwt.

(6) Equations derived are as follows: $T = \frac{W \times S}{2 \times bd^2} \times W = \frac{2 \times T \times b\,d^2}{T}$ where T = tenacity in tons sq. in.; W = ultimate load in cwt. at centre of bar; S = span in feet, b and d being breadth and depth in inches.

(7) Bars and links cut out of casting give much lower results than bars and links cast separately, say 30 per cent less.

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A MODE OF HEATING FROM A CENTRAL SOURCE. By Sir FREDERICK BRAMWELL, F.R.S., V. P. Inst. C. E.

[ABSTRACT.]

A DESCRIPTION of the method of warming employed in the Third Middlesex County Lunatic Asylum, Banstead, England, where the circulation of warm water is produced by centrifugal pumps which maintain parallel mains in a relatively plus and minus condition.

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FLOOD REGULATOR. By JAMES DILLON, C. E., Glengeary, Co. Dublin, Ireland.

[ABSTRACT.]

THIS flood regulator is used for two purposes: to reduce the cost of river excavations or conservance works by reducing the volume of flood sent down a river in a given time, and for preserving for dry seasons some of the waters now allowed to pass to the sea in wet seasons unused.

The author has effected this in places where large natural lakes are found to exist at the head of a river system proposed to be improved, by increasing the natural range of the lakes one, two or more times more than their ancient range between high and low water by deepening the river channels into them; of course this operation would in itself increase instead of diminish the flood discharge.

To prevent this increase, he constructs large self-acting sluices on down-stream side of lake, kept open in dry seasons, having their sills to correspond with the new low water level of the lakes. On the floods entering the lakes they escape through these sluices, and by the time the maximum discharge is reached the sluices are closed, gradually, by the action of iron floats rising with the flood surface of the lake; then by the time the sluices are completely closed the maximum calculated flood discharge is found to be passing through the permanent boat or ship-pass at all times kept open at one side of the weir for the preservation of water-supply to lower countries, for navigation, fishing and other rights.

This maximum flood discharge, however, cannot be reached through this ship-pass until the lake is made to withdraw from the ancient maximum floods the increased flood volume required for dry seasons, and by operating on the regulating screws attached to the sluices, ordinary floods can be reduced or increased with the greatest nicety, etc.

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AUTOMATIC SOUNDER. By JAMES DILLON, C. E., Stratford House, Glengeary, Co. Dublin, Ireland.

[ABSTRACT.]

THIS instrument has been successfully used for some time by the author for preparing soundings of lakes, harbors, estuaries, rivers, for chart and sections, etc.

The instrument consists of wire, bars, or tubes of metal or other substances, of suitable lengths, made to hang freely and vertically from the center of a dial (on which are marked feet or fathoms) fixed to side of a boat, steamer or other vessel.

On moving the boat, etc., over a shoal or other obstruction under the water, this bar which hangs vertically and points to its maximum length on the dial will strike the shoal at its maximum length of ten, or fifty or more feet, and will be raised ten or more feet toward the surface of the water pointing to this same number of feet or fathoms on the dial and should the shoal reach top of water so will the sounding bar, while the dial end of this bar points to zero on the dial.

The vibrations of the bar differ in degree when passing over mud, gravel, rock, etc., thus recording the same.

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EXPERIMENTS ON BELTING. By Prof. GAETANO LANZA, Mass. Institute of Technology, Boston, Mass.

[ABSTRACT.]

IT has been customary to determine the coëfficient of friction for belting by hanging a piece of the belt to be tested over a fixed pulley and suspending various weights, $T_1$ and $T_2$, from its extremities, the weight $T_1$ being in each case just enough greater than $T_2$ to cause the belt to slip on the pulley. From these values of $T_1$ and $T_2$ the coëfficient of friction may be calculated by the formula (adapted from Rankin's Applied Mechanics, page 351)

$$f = \frac{\text{hyp. log. } T_1 - \text{hyp. log. } T_2}{\pi}.$$

If we compare the results thus obtained by General Morin, Henry R. Towne, Edward Sawyer and others we shall find that they differ widely from each other.

General Morin's results are:—

New belting on smooth cast iron, dry, .284; wet, 377. Belting on rough cast iron, new, 281; old, 279. Mr. Towne gives an av-

tests lasted usually about 100 minutes, with indicator cards from both ends of the cylinder, and readings of the number of revolutions, boiler pressure, and weight of condensed water every 5 m.

| No. of experiment..... | 1 | 2 | 3 | 4 | 5 | | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Revolutions per min.. | 68.8 | 66.0 | 67.1 | 63.8 | 68.6 | 62.9 | 63.9 | 62.4 | 68.3 | 65.1 | 34.0 |
| Boiler pressure..... | 71.1 | 71.9 | 73.6 | 70.6 | 56.8 | 54.7 | 73.2 | 74.2 | 76.1 | 75.8 | 73.0 |
| Horse power..... | 2.44 | 8.17 | 8.60 | 13.27 | 1.78 | 10.39 | 8.87 | 12.06 | 6.02 | 15.87 | 4.45 |
| Cut-off in per c't stroke | 1.0 | 10.1 | 9.6 | 23.7 | 1.5 | 37.0 | 35.2 | 41.5 | 18.2 | 40.4 | 8.0 |
| Pds. water per horse power per hour.... | 112.9 | 51.8 | 45.7 | 41.2 | 149.3 | 59.0 | 63.3 | 53.5 | 57.0 | 39.0 | 63.1 |
| Per c't steam at C. O.. | 16.7 | 32.5 | 35.5 | 47.7 | 17.0 | 50.6 | 63.9 | 66.2 | 40.2 | 59.8 | 23.1 |
| Per c't steam at release | 66.9 | 63.6 | 65.3 | 65.2 | 67.7 | 57.6 | 80.1 | 78.9 | 70.8 | 68.4 | 55.0 |
| Per c't reëvaporation. | 50.2 | 31.1 | 29.8 | 17.5 | 50.7 | 7.0 | 16.2 | 12.7 | 30.6 | 8.6 | 31.9 |
| Back pressure..... | | | | | | | 22.2 | 16.8 | | | |
| Initial cyl. pressure.... | | | | | | | | | 50.4 | 64.9 | |

In experiments 1 to 4 the cut-off was varied; 5 and 6 show a lower boiler pressure; 7 and 8 a large back pressure; 9 and 10 were made with a throttling governor; and 11 was made at about half normal speed. The horse power and point of cut-off were obtained from the indicator cards. The percentages of steam at cut-off and release were obtained by calculating, from the cards, the weights of steam in the cylinder at those points, and dividing it by the weighed amount of water used per stroke plus the weight, obtained from the cards, of steam in the cylinder during compression. The difference of these two percentages is the per cent of reëvaporation.

The most noticeable feature of the tests is the large quantity of water per H.P. per hour, and the excessive reëvaporation due to short cut-off. Various other points will appear upon a careful comparison of the data.

Three tests were made with a Porter-Allen engine, but the data obtained indicate nothing worthy of remark.

The following experiments were made by Mr. Purinton to determine the actual speed of slip of a 10 in. double belt, which transmits power (advantageously up to about 16 H.P.) from the fly-wheel of a Harris-Corliss engine.

| SPEEDS IN FEET PER MINUTE, FLY WHEEL RIM. | SLIP. | PER CENT OF SLIP | INDICATED. H. P. | WEATHER. |
|---|---|---|---|---|
| 1467 | 13.80 | 0.94 | 19.77 | Relative humidity, .47. |
| 1494 | 13.10 | 0.88 | 15.58 | Relative humidity, .46. |
| 1479 | 34.98 | 2.37 | 20.37 | Cloudy and damp. |
| 1503 | 23.69 | 1.56 | 20.07 | Bright and sunny. |

From these experiments it would seem that Mr. Towne's coëfficient is too large, and although we have not experimented with speeds between 13 and 30 ft. (our speed being nearer 2 ft. per. m.) the coëfficients determined must be nearer the truth than those obtained with 200 ft. of slip per minute.

The experiments will be continued and we hope eventually to be able to formulate: I. The maximum power, which a given belt running at any given speed will carry. II. The amount of slip of the belt when running at a given speed and transmitting a certain amount of power.

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STEAM ENGINE TESTS. By Prof. C. H. PEABODY, Boston, Mass.

[ABSTRACT.]

IN the winter of 1883–4 a number of experiments were made by the fourth year class in the mechanical laboratory of the Massachusetts Institute of Technology, the results of which are here given. They were made mostly on an 8″ × 24″ Harris-Corliss engine running with a normal speed of 60 revolutions per minute, the power being absorbed by a friction brake, and the steam being condensed in a surface condenser at atmospheric pressure and afterwards weighed. A fairly uniform back pressure was produced, when required, by throttling at a distance from the engine. The

put the price equal to gas at $1.69 the company would earn 20 per cent. additional, making its profit in all 30 per cent.

A further and most important saving can be made by heating the buildings by means of the exhaust steam from the engines, so that in winter but a part of the whole expense could be chargeable to the electric lighting, $8000 to $9000 might thus be saved, bringing down the cost to that of gas at $1.48 while affording seven per cent additional profit. The largest item of cost is lamp-renewals and we may be reasonably confident that the average life of lamps will be greatly increased and that their cost will be much reduced. There seems to be therefore no reason why the electric light for domestic purposes should not at once be a paying investment, as it is known to be in numerous cases where isolated plants have been introduced in manufactories, and other places of business.

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TRAINING FOR MECHANICAL ENGINEERS[1]. By Prof. GEO. I. ALDEN, Worcester Free Institute, Worcester, Mass.

[ABSTRACT[2].]

PROGRESS in education is secured by the aid of forces outside and above the schools. When a few have made discoveries in science or advancement in art or in engineering they have set a standard which must thereafter be the aim of educators. Mechanical engineering as taught in schools is subject to the general law of progress. While it is taking a high rank as a liberal profession and offers a broad field for the activity of the best powers of young men who enter it, yet it must look for progress to two main forces,

[1] This paper was presented in response to the announcement of the Secretary, that one or more sessions would be devoted to the discussion of the "Best methods of teaching mechanical engineering." Owing to a variety of untoward circumstances, other expected papers did not come to hand in time, but an exceedingly lively and interesting discussion was aroused. This was participated in by a number of prominent mechanical engineers and teachers and other scientists, and it was unanimously decided that the discussion must be continued. The following gentlemen were accordingly appointed a committee to secure the active coöperation of leading men in a fuller presentation and discussion of the subject at the next meeting: J. Burkitt Webb of Cornell University, Ithaca, N. Y., Geo. I. Alden of Worcester Free Institute, Dr. C. M. Woodward of Washington University and A. Beardsley of Swarthmore College.

[2] Printed in full in the American Engineer, Oct. 3 and 10, 1884.

ECONOMY OF THE ELECTRIC LIGHT. By ALLAN STIRLING, N. Y. City.

THE combustion of carbon is the source of the light with both gas and electrical lighting, but a marked difference occurs from the fact that in the former case the carbon must be carried to the point where the light is needed, while in the latter it is burned under a steam boiler at any suitable place, and only the resulting energy in shape of electricity, need be carried to the lamp.

To compare the two systems assume ten blocks of houses requiring in all 12,000 seventeen candle power lights; suppose that in summer one-third of these will be used three hours per night, and in winter two-thirds for four hours. The cost of gas in N. Y. city for these lights will be at the rate of five feet per burner and $2.25 per thousand feet—$24,600 for the summer half, and $65,700 for the winter half of the year; total $90,300.

The items of the cost of electric lighting are; coal and water for boilers, attendance, lamps, miscellaneous supplies, repairs and depreciation, interest. At the rate of one horse-power for every eight lights, and three pounds of coal hourly per horse-power, with coal delivered at $5 per long ton, the yearly coal bill will be $6750.

For water $457 will be needed, supposing 27 lbs. needed per horse-power, at 13½ cents per 1000 gallons. With lamps costing 90 cents each and lasting 600 hours the cost of renewals would be $12,000. For miscellaneous supplies $750 may be allowed. By properly directing and economizing the labor of the attendants the work may be done by one engineer and one or two firemen, so that, at $4 and $2.50 respectively, we shall need $2800 for attendance.

The plant will cost say $15,000 for ground and buildings, $50,000 for engines and boilers and $40,000 for dynamos, and the cost of wiring and fixtures may be omitted to balance the cost of pipes and fixtures for gas. For repairs and depreciation on this plant we will allow $10,500, with a like amount for interest. The total yearly amount will therefore be $43,800, giving a difference in favor of electricity of $46,500, and showing that the latter can be furnished at less than half the present price of gas or as cheap as it would be at $1.12 per thousand; or, supposing we divide the saving between the electric light company and its customers and

put the price equal to gas at $1.69 the company would earn 20 per cent. additional, making its profit in all 30 per cent.

A further and most important saving can be made by heating the buildings by means of the exhaust steam from the engines, so that in winter but a part of the whole expense could be chargeable to the electric lighting, $8000 to $9000 might thus be saved, bringing down the cost to that of gas at $1.48 while affording seven per cent additional profit. The largest item of cost is lamp-renewals and we may be reasonably confident that the average life of lamps will be greatly increased and that their cost will be much reduced. There seems to be therefore no reason why the electric light for domestic purposes should not at once be a paying investment, as it is known to be in numerous cases where isolated plants have been introduced in manufactories, and other places of business.

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viz., the influence of the scientific attainments and practical achievements of those foremost in engineering science and practice. A school for training mechanical engineers is properly a professional school, and should hold up its standard of professional training, in order that it may demand in candidates suitable preparatory, general training for matriculation. It should aim to fit young men for immediate usefulness in the profession, and to lay the sure foundations for a growth which shall enable them to take up the unfinished work of the engineers of this generation and carry it forward into the next century of progress. To aim at practical achievements is not enough; for the man is more than his profession. Scientific attainments are not alone sufficient. The ability to apply knowledge to practical ends is valuable in discipline as well as necessary to professional success. The necessary scientific attainments are more than mere knowledge of facts and principles. The evidence of such attainments is the ability— within a sufficiently wide range of inquiry—to give accurate answers to definite questions. To secure this ability the usual studies in the curriculum of the schools should be thoroughly taught by direct methods, with the aid of numerous and well selected problems, and laboratory work. The problems should be, as far as possible, actual engineering problems that the student may secure that complete assimilation and personal appropriation of the subjects taught throughout the course, which characterize the scientific attainments toward which the school should aim.

The practical achievements of the engineer are closely related to machine-shop methods and practice. All his designs must be sent to the shop in a form consistent with such practice. To secure knowledge of machine-shop methods, limitations and possibilities, most schools have a practical or shop department in their engineering course. It is important that the successful engineers of the country should say what such a shop should be and what it should accomplish. The shop is made a department in the course in order to add to the school methods as well as to its facilities for instruction. It should not, therefore, be such an institution as would be developed by, or out of, the school. It should bring to the school its own methods and standards. It should be superior in all its appointments for practical, constructive and engineering work. It should have not only the tools, methods and facilities but also the business of a leading productive shop. It will then

be able to adopt, in a full measure the modern methods of instruction aimed at in other departments. Its work will be in accordance with the economical principle of teaching analysis and synthesis in close connection. Work on real valuable products has elements of training which are lacking in work on simple isolated pieces. It cultivates practical judgment, gives valuable experience and available skill. The connection of the shop with the school is an advantage to the shop, and a stimulus to breadth and thoroughness in other departments. It promotes symmetry and harmony in the whole training without detriment to any of its qualities and economizes by variety of occupation the time spent in the school. About ten hours per week, spent in such a shop, will, in four years, give the student as much skill (and more general ability) in the shop, as a three years ordinary apprenticeship. This opens to every graduate a wide door to the engineering profession, giving at once opportunity for talent and independent self-support. Such practical attainments are secured by the construction in the shop of products for the open market. Only in this way will it be practicable to keep up the standard of workmanship and design and the practical methods of engineering practice. From fifty to one hundred thousand dollars for shop and equipment would give provision for instruction of 100 students, and from three to ten thousand dollars would be required for annual running expenses. Experience indicates that money expended, in founding and fostering such a shop department as above outlined, will yield a large return both to the individual students and to the profession.

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TOPOGRAPHY OF MACHINES. By OBERLIN SMITH, M.E., Bridgeton, N. J.

[ABSTRACT.]

THERE is a serious lack of system in our machine-building practice regarding verbal descriptions of positions and motions. This causes ambiguity in both written and oral explanations; which are necessary, in new machines, in addition to drawings.

An instance of this is where some member of a machine has a so-called *front* of its own, facing in a different direction from the main front of the machine.

The remedy is to always assume one side as a *front* and let the fronts of all pieces, when in position shown on drawings, face in the same direction. Let *left* and *right* be rated by the hands of the operator as he stands in *front* of stationary machines facing them; and as he stands *upon* moving machines, such as boats, vehicles, etc., facing forward. This will give a relatively different position of sides in the two classes but it will make no difference if all views on drawings are plainly marked "front," "top," etc.

Let all directions be defined, in the whole machine or a separate piece, as either "forward," "back," "right," "left," "up," "down;" and all sides as "front," "back," "right," "left," "top," "bottom." Let all positions *referred* to some *other point* be "front of," "back of," "right of," "left of," "above," "below." Let all measurements be in rectangular directions if linear. If angular let them count from some rectangular line.

By using these rules a designer can finish designs of intricate machines through his assistants, communicating by mail and even telephone.

The writer is working out a system, as yet in a crude state, for carrying the above principles toward an ideal condition where a machine could be wholly described by figures and letters, without any drawings at all. Practically it would supplement, simplify and elucidate a set of drawings rather than wholly supplant them. The general idea embodied is to locate any desired point in a machine, or other object, by a perpendicular measurement from each of three "reference planes," all at right angles to each other and (usually) forming three adjacent sides of a cube exterior to the machine, each measurement being recorded upon the drawing prefixed by a letter U, R, or F, representing up, right or forward, respectively. This system has already been partially applied to taking measurements of old machines, to get data for making drawings, and has proved much superior to the random method usually practised of measuring from anywhere to somewhere.

In plotting down such a survey as has just been referred to, it will be found of great benefit to use cross-ruled drawing paper, preferably graduated to inches, and their halves, quarters and eighths, the inch lines being the heaviest. These lines should be numbered from one edge of the paper each way, and their use is just as important as are the lines of latitude and longitude in copying a map drawing.

The writer herein claims no new principles, but merely the applications of some very old ones, and as yet in a somewhat imperfect way, to the ordinary operations of machine shop practice. Such a reform as is here foreshadowed is most urgently needed as one of the means of systematizing the work of the mechanical engineer. It is, in fact, only the common sense use of methods which have long been employed by the geographer, the topographical-engineer, and even by the landscape-gardener and the railway contractor.

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DRIVEN WELLS.[1] By J. C. HOADLEY, M. E., Boston, Mass.

[ABSTRACT.]

THE investigations of Darcy, Dupuit and Lueger, and the experimental determinations of Piefke and others, relating to the flow of water in porous earth, are recognized. Some unfounded assumptions, and fallacious theories and unsound explanations of these, by courts and experts, are pointed out. Description of the method of conducting experiments which should place in a clear and convincing light the truths of nature, relating to the flow of water from the natural height of the surrounding ground water, down an obstructed hydraulic slope, by gravity alone, to the depressed surface of the water immediately around the suction pipe of a pump and in wetting contact therewith, whether such suction pipe be driven or otherwise inserted in the ground, or put into the open water of an ordinary well:—

*First*, by pumping from actual tubular wells inserted in natural water-bearing soil, and marking the effect both as to the quantity of water obtained and slope of water-surface produced, in comparison with corresponding results by similar pumping from a small open well; and, *second*, by laboratory experiments with pumps, working under various conditions in artificial filtering tanks, supplied with appropriate measuring, indicating and recording apparatus.

[1] This paper is printed in full, with illustrations, in the Sanitary Engineer for December 4, 11, 18, 25, 1884.

Special points of investigation were:

1. As to the alleged difference between open wells and driven wells in point of efficiency in obtaining water from the ground.

2. As to the alleged difference in the same respect between pipes driven tightly into the ground "without the removal of any earth upward," and similar pipes under like conditions inserted loosely in holes bored for them.

3. As to the alleged newly discovered "principle," or "power of nature," according to which, it is alleged, a pump producing a partial vacuum in a suction-pipe, may, provided the suction-pipe be "driven tightly into the ground," cause water not in contact with the exterior surface of the suction-pipe, to flow towards the pipe, and up to wetting contact therewith, otherwise than by the force of gravitation causing it to percolate through the pores and interstices of the soil with a rapidity proportioned *directly* to the slope, *i. e.*, to the difference of level produced by pumping, in a given horizontal distance, and *inversely*, to the obstruction of the soil.

4. To ascertain as far as possible, by direct experiment, the form of the curves of such obstructed hydraulic slope.

The true theory of the flow of underground water as set forth by the physicists first above named, fully sustained by the results of the experiments, and the pretentious fallacies above referred to completely refuted.

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ON A NEW METHOD OF PRODUCING SCREWS OF STANDARD LENGTH AND UNIFORM PITCH. By PROF. WM. A. ROGERS, Harvard College Observatory, Cambridge, Mass.

[ABSTRACT.]

DESCRIPTION of the process by which a half-meter screw of the dividing engine constructed for Prof. W. A. Anthony was made, together with a discussion of methods by which further improvements may be made.

DEVELOPMENT OF THE PHILOSOPHY OF HEAT ENGINES. By PROF. R. H. THURSTON, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

THIS paper presented an historical sketch of the development of the modern, and the now accepted theory, of heat engines, including the study of wastes. This paper was read at Montreal before the B. A. A. S., by request, and was offered in Section D, of the A. A. A. S. by request of members of the Section.

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THREE PROBLEMS IN RIVER PHYSICS. By PROF. J. B. JOHNSON, Washington University, St. Louis, Mo.

IN the past five or six years, there has been a great deal of money spent upon, and study given to, many questions of a scientific nature pertaining to the improvement of our western rivers. Your attention is called to some conclusions that may be drawn from recent investigations on the three following problems:

I. The Transportation of Sediment and the Formation and Removal of Sand-bars.

II. The Flow of Water in Natural Channels.

III. The Relation of Levees to Great Floods, and to the Low Water Navigation of Rivers.

I. *The Transportation of Sediment and the Formation and Removal of Sand-bars.*

The solid matter carried by streams of variable discharge and cross-section, flowing over sandy beds, is at once the cause of, and remedy for, most of the obstructions to the navigation of such streams. A proper understanding of this subject is a prime requisite to an adequate conception of the conditions governing the flow of water in natural channels, the improvement of low water navigation, flood confinement, etc.

In all natural water courses, the material carried by the stream may be graded according to the method of its transportation, as,

*First*, That carried in continuous suspension.

*Second*, That carried in discontinuous suspension.

*Third*, That carried by rolling on the bottom.

*Sediment in Continuous Suspension.* This is composed of such finely divided particles of clay and mud that any slight disturbance of the water in a vertical direction is sufficient to prevent its deposition, and so it mostly remains in suspension until it reaches the sea. A large part of the sediment carried by the Mississippi River is of this class. It mostly comes from the western tributaries, more especially from the Missouri. If a quart of this water be placed in a glass jar, and set away, it requires some ten days for the water to become clear. Evidently, this kind of sediment does not form sand bars, neither can the engineer avail himself of it in building artificial banks in contraction works. It is therefore of no consequence to the river engineer. It is neither helpful nor harmful, and may be ignored.

*Sediment in Discontinuous Suspension.* This kind of sediment is composed of sand, more or less fine according to the velocity of the stream. It is the material of which sand bars are made, and it is also the material out of which the engineer builds his artificial embankments by the square mile behind his permeable dykes. It is constantly being picked up at one point and put down in another by the action of a law as unchangeable as the law of gravity. In the river's tireless efforts to attain a uniform flow it is constantly scouring out the engorged sections, and filling in the enlarged sections. For any given stage of water, the volume discharged at successive sections is the same, but since the sections do not have equivalent areas, the mean velocity at successive points is a constantly varying quantity. The river undertakes to overcome this inequality and so engages in an enormous carrying trade, which consists in cutting out the bottom where the section is less and the velocity more, and carrying this sand to the first point below where the section is more and the velocity less, and there it is deposited. Evidently, if any given stage of water should continue long enough, this double action of scouring the small sections and filling the large ones would result in a nearly uniform flow, when such small particles as could be carried by the resulting velocity would be so carried in permanent suspension, leaving a bed of tolerably permanent character, being only influenced by the matter rolling on the bottom. But here comes the trouble. No sooner has the river set to work to adjust itself to any given stage, than behold, the stage changes, and then it must go to work, cutting and filling at new points, and as the stage is ever changing, the river is ever beginning anew in its endless task.

It may not be clear why this change in stage should so disarrange matters. Let us see. The cause is the great variation in width. Take an actual case. At Plumb Point, on the Mississippi River, sixty miles above Memphis, the following extremes were found in 1879 on a reach eight miles in length.[1]

| | | WIDE SECTION. | NARROW SECTION. |
|---|---|---|---|
| Surface width, in feet, | High water. | 8840 | 1680 |
| | Low " | 7330 | 1375 |
| Mean depth " " | High water. | 23.9 | 60.7 |
| | Low " | 6.0 | 23.9 |
| Area of section in sq. ft., | High water. | 260000 | 94500 |
| | Low " | 30220 | 68500 |
| Mean velocity in ft. per sec. | High water. | 3.67 | 10.1 |
| | Low " | 2.65 | 1.15 |
| Fall per mile in feet, | High water. | 0.26 | 1.75 } [2] |
| | Low " | 1.15 | 0.07 } |

Thus, at low water, the wide section had a mean velocity of 2.65 feet per second, while the narrow section had a mean velocity of only 1.15 feet per second. At a stage 26.6 feet above low water (which in the table here given is called "high water," although it is some eight feet below extreme high water) the conditions are reversed, for now the wide section has a mean velocity of 3.67 feet per second, while the narrow section has a mean velocity of 10.1 feet per second. Here the wide section was some eight miles above the narrow one. Evidently the river is cutting out the shoal and filling up the pool in low water, and cutting out the pool and filling on the succeeding shoal in high water, and in fact this is what is always observed to occur.

The amount of this local scour and fill on the Mississippi river is enormous. In the case above noted there was a total scour over the reach of 350,000,000 cu. ft. or enough to cover one square mile to a depth of 11 feet. This occurred from Nov. 13 to Jan. 3. In many cases the rate of fill and scour, as well as the total amount, is much greater than this. It is not uncommon for the shoal places to be built up as much as from six to ten feet in time of high water, so that the bottom of the river is then higher than

[1] See Report of Miss. Riv. Commission for 1881, p. 69.
[2] From plate 7, p. 120 of same report.

the surface of the water will be after this same fill has been cut out by the succeeding low water. In other words, the river bed is a succession of narrow, deep pools, alternating with wide shoals. The pools are in the bends, and the shoals are on the crossings. The shoals are like so many dams, fifty to seventy-five feet in height, stretching across the river bottom say every ten miles. In high water these wide dams are built several feet higher, and the narrow pools are dug several feet deeper. In time of low water the dams are scoured down several feet, and the material deposited in the succeeding pool. What is true on the Mississippi river on a large scale, is true of every stream flowing in a friable bed, on a corresponding scale. This sediment is, therefore, said to be in temporary or discontinuous suspension. It settles very quickly where a sample is caught in a vessel, and the amount carried by the river is only determined by taking samples at various depths. There is little of it near the surface, except when there is violent vertical agitation, as in "boils" and eddies. It is constantly and rapidly falling towards the bottom, and is only prevented from reaching it by the upward motion of the medium.

*Material transported by rolling on the bottom.* When the grains of sand are too large to be held in temporary suspension they may yet be moved along on the bottom from being unable to resist the force of the current. This motion is also mostly discontinuous inasmuch as the particle is pushed up the gentle slope of the upper side of a sand wave or reef, and dropped upon the abrupt down-stream side, there to remain until the reef has progressed so far as to again expose it to the action of the water on the up-stream side. The amount of material so transported is fairly represented by the size and rate of travel of the wave.[3] These sand waves, or reefs, may be as much as 8 to 15 feet high, extend from one-half to three-fourths the distance across the river, and move from 10 to 30 feet a day. They succeed each other at intervals of some 300 feet. The same action is seen by the roadside, on a small scale, after a shower. It obtains in all natural water courses, is found in both pool and shoal alike, but is most strongly developed on the shoals. It is largely instrumental in the formation and removal of sand bars, but is of little use to the engineer in building embankments. It is in this way, however, that the slow currents of a low stage may cut a channel through a wide and high bar.

[3] See Report of Chief of Engrs. U. S. A. for 1879, Vol. III, p. 1963; also, Reports of Miss. Riv. Com. for 1881 and 1882.

Although the mean velocity may be small, the bottom velocity is relatively large on account of the shallow depth. The period of its action is also apt to be longer than that of flood stages. The amount of matter so transported is, however, small on the Mississippi river, compared to that carried in suspension. A knowledge of this action is mainly important as going to explain the regular changes that are observed to take place on the bottoms of cross-sections of rivers.[4]

## II. *The Flow of Water in Natural Channels.*

It is now generally admitted that no formula, involving only the variable functions of slope and cross-section, can ever be used to give even approximate values of the mean velocity, across a given section, of a stream flowing in its natural or irregular channel. Farther than this, we are now forced to the conclusion, that no such formula can ever be used to give the continuous discharge of a single stream, at a given station, even though the actual observed mean velocities on that section, for one year, be used in its derivation.

The common type of formula is

$$v = c\, r^m\, s^n$$

where

$v$ = mean velocity across the section.
$c$ = a constant coëfficient, either general, or specially derived for each case.
$r$ = hydraulic mean depth = $\frac{\text{area of section}}{\text{wetted perimeter}}$
$s$ = slope = sin. of angle of inclination to the horizontal.
$m$ and $n$ are usually taken as $\frac{1}{2}$.

The Chezy formula, which is of this type is:

$$v = c\sqrt{rs}.$$

Most of the efforts made to adapt this formula to the flow of water in natural channels have been spent upon the coëfficient $c$.

It is, however, no longer a question of coëfficients or exponents. For regular and stable channels, like flumes, canals, or ponds controlled by fixed weirs, formulæ can readily be deduced that will give fair results, but in all natural channels, the cross-section, slope, and flow, are so irregular, and the bed so changeable, that the variables affecting the flow are not adequately represented by $r$ and $s$, and hence, any formula based on these for the independent variables will surely fail.

A body of finite mass, moving under constantly varying accel-

[4] For an article on "Silt movement by the Mississippi" by Robt. E. McMath, see Journal of the Association of Engineering Societies, v. 1, p. 266.

erating and retarding forces, never has a velocity at a given point which is a function only of the forces acting at that point. Since the accelerating forces of a stream are due to the slope, and the retarding forces are due mainly to bed and banks, and since the conditions of slope, bed and banks are constantly changing in the progress of a given mass of water down stream, it follows that this mass is subject to constantly varying forces. The velocity of this mass at any section is therefore a function of the slope and bed for an indefinite distance above, and can never be predicted from the immediate conditions at the section.[5] Whether or not it can ever be predicted, within reasonable limits, is still a question, but some new light has recently been shed on this much mooted subject. If the conditions of slope, approach, cross-section, and discharge, should be always the same at the same stage of water, or for the same stage and same rate of rise or fall, then a cycle of observations on mean velocity might enable us to predict what the next cycle of mean velocities would be at that same section. But, as outlined above, in discussing silt movement, it is seen that, in streams of unstable *regime*, the bed is constantly shifting, and that the high ridges, or bars, that alternate with the pools, are constantly changing their height. If these ridges be conceived as weirs, and the stage of water in the intercepted pools be controlled by these weirs, which it is in medium and low stages, then the discharge in this pool may be discussed with some confidence and profit. If the section be located in the lower portion of the pool, so that the conditions of approach over the weir above be of little consequence, then the conditions effecting discharge are, the *effective head*, that is, the surface slope from the section to the weir below, and *the depth on the weir*. The origin, from which the stage should be measured, in this case, is the natural zero of hydraulic activity, viz.: the horizontal plane passing through the crest of the weir. When so taken, a very simple relation is found to exist between *stage* and *mean velocity*, inasmuch as the latter is a linear function of the former.[6]

[5] The problem is similar to the instantaneous relation existing between the pressure on the piston of a crank engine, the resistance to motion, and the velocity of the fly wheel. No one would for a moment suppose that a formula could be derived that would express this relation for any given instant, and yet this is exactly what has been attempted on streams for the last one hundred years.

[6] The locus is probably an hyperbola, which becomes practically a straight line for all stages above a few feet. See paper by R. E. McMath before Am. Soc. of Civil Engineers. V. 11, No. 239.

If this relation be determined by observations at that section, then it may safely be used *so long as the weir condition remains fixed.* When this changes, by scour or fill of the bar, then the origin of the locus changes with the change in origin for stage. But the weir condition could be made the subject of observations, and the locus of the curve of mean velocity and stage so adjusted as still to indicate the mean velocity for this locality, provided the section on weir, or bar, should remain the section controlling, or limiting, the discharge. In high stages, the region over the weir becomes itself the comparatively stagnant pool, and the controlling or limiting section is in the deep and narrow bend below. The low slope is now over the shoal, and the steep slope in the deep pool. This slope is used to generate the accelerated velocity through the engorged section. The conditions of a slack pool, retained by a submerged horizontal weir, now no longer obtains, and the narrow, deep reach around the bend with high slope, is similar to an engorgement by lateral contraction. This is a very different problem, evidently, from what we had at a lower stage when the weir section was the limiting one, and a discussion of this state of affairs offers greater difficulties than the other. As a striking example of this change of location of the engorged sections, see the table given above in discussing the movement of sediment. Thus, in low water, the deep section had an area of two or three times that of the shoal section, and a slope of one-sixteenth as great, while at high stage, the deep section had an area of only thirty-six hundredths of that of the shoal section, but its slope was seven times as great.

The object of this presentation is not to discuss or derive formulæ, but to call attention to some of the heretofore neglected functions of the problem. These functions are seen to be so various, and apparently lawless in their nature, that it is highly improbable that we shall ever be able to obtain any formula of much value. A service has been rendered, however, when the impossibility of a successful solution on the lines of investigation so long pursued has been pointed out. Also, when the real determining causes effecting flow are properly conceived and investigated, rational and valuable formulæ may be obtained for exceptional cases of stable conditions.

*III. The relation of Levees to Great Floods and to the Low-water Navigation of Rivers, as illustrated by the Mississippi River.*

That levees may be built which will confine the greatest flood on the Mississippi river, without danger of their giving way, may be admitted. The question is, What shall be their size and location?

The location of a levee is determined by two considerations in favor of putting it as near the bank as possible, and by two others in favor of putting it as far away as possible. The arguments in favor of putting the levee near the bank are:

*First.* The land near the bank is generally higher than anywhere else. There is generally a well defined slope away from the river, and therefore a levee here, to confine a given flood plane, will have the minimum height and cost.

*Second.* The land near the river bank is always most valuable for cultivation on account of its being higher, and therefore the protection of this narrow strip is the chief cause for leveeing the river at all.

The arguments in favor of putting the levee at a distance from the river are:

*First*, so that it will not soon fall into the river from caving banks, and *second*, So that the facilities for flood discharge may be greater, and therefore, the flood stage and necessary height of levee less. This latter argument is so generally advanced that it is deserving of mention, but I will try to show that it is more visionary than real. The force of the other arguments above stated is evident, and they need no further discussion.

The height required for levees in a certain locality is a very complicated problem, and unfortunately for the lower Mississippi river it is a problem on which we have no direct evidence. By having no direct evidence, I mean that as there is no point on the river below Cairo where the whole of a great flood has ever been confined between levees, so there is no argument from experience.

In this dilemma we are forced to fall back upon theoretical considerations.

For the past three years, 1882, '3 and '4, we have had great floods on the Ohio and Lower Mississippi rivers, and a great deal of data has been obtained, such as we have never before possessed.

The first installment of this flood data may be found in the Report of the Mississippi River Commission for 1883.[7]

The overflow water of a great flood loses itself out over the west bank of the river from Cairo to Memphis, passes down through the St. Francis swamp, and is forced back to the river again by the high bluffs at Helena. It then overflows the east bank, passes down through the Yazoo bottoms, and is again forced back to the river by the bluffs at Vicksburg. It then once more crosses the channel and escapes over the west bank to return no more, but to find its way to the gulf through the Tensas and Atchafalaya river regions.[8]

Notwithstanding the river has been leveed almost from Cairo to the Gulf, and in the lower parts of the valley these levees have been carefully maintained and gradually enlarged, yet in time of a great flood the surplus water seems quite oblivious of such frail barriers, and always goes over and through them very much as though it were quite unconscious of their presence. And every time the levees are destroyed the people seem as much astonished as though that were the first time such a calamity had ever befallen them. The trouble is that due weight has not heretofore been given to the enormous quantity of water passing outside the channel. Before the flood of 1882 no even approximate determination of the amount of such water had ever been made, and no one suspected it to be so large. From the observations taken on that flood, which was the largest on record, we find that on some zones, or belts, there was about as much water passing outside the channel as there was in the channel. The total maximum discharged in that flood was some 2,000,000 cu. ft. per second, while for a hundred miles (by river) at and above Lake Providence, and for another hundred in the vicinity of New Orleans, the discharge in the channel, with overflowing banks, was but 1,000,000 cu. ft. per second. The other million was finding its way to the gulf through the swamps. This is a very startling fact. It means that if we propose to completely confine the waters of a large flood between levees, we must, in places, carry twice

[7] Supplemented in the Report of 1884, by several reports on the observed volume of the overflow water in the flood of 1882, including one by the writer on the Flood Discharge through the Yazoo Bottoms.

[8] See paper by the writer on "Great Floods on the Lower Mississippi," in Journal of the Association of Engineering Societies, v. 2, p. 115.

as much water as the present channel can take. At all points below Cairo, it is now pretty well known how much more water would have passed in a confined channel, than did so pass in the flood of 1882. With such facts as a basis for estimates, engineers still differ very widely as to the necessary height the levees must have to confine these additional volumes. Some engineers affirm that the levees need be but little, if any, higher than they now are, while others insist that in places they will have to be from ten to twelve feet higher than they now are. The whole question turns on whether or not the bed of the river will scour out when all the water is confined to the channel. The popular conception, as well as the expressed opinion of most writers on the subject, is to the effect that a confining of the waters to one channel will increase the velocity of the stream (which everybody admits), that this increased velocity will give increased scour (which everybody admits, in a sense) and that this increased scour will result in a general lowering of the bed (which must be denied).

In other words, there are two schools of engineers, the concentration school, and the equalization school. The former affirms the beneficial results of an increased volume at high stage; the latter not only denies any beneficial results but affirms that actual harm would ensue. Again the question turns on the methods of transporting sediment. The concentration school argue as though all sediment were of the continuous type, and when once taken up it would be carried to the sea, provided all the water remained in the channel. But they say, in effect, that in case of a flow over the bank, while the water pauses to consider whether it shall go over the bank or remain in the channel, the sediment escapes from its grasp and settles to the bottom. On the contrary, we know, that when two forces, at right angles to each other, act on a moving particle, it moves over a path which is a resultant of the two forces, and so moves faster than if either force acted alone. Therefore, instead of the water being checked by the escape over the bank it is really accelerated. Again, the more the energy of a river is increased by increasing the stage the more unequal becomes the difference in area of successive sections in wide and narrow places, and at high stage the narrow and deep places are always the engorged sections. If the energy of the river be increased at this stage it simply scours out the deep places deeper,

and drops this matter on the succeeding wide shoal. That is, any influence towards a temporary adjustment of the river's bed to a high water discharge is an influence which is adding to the heights of all the sand bars on the river. The greater the stage, the higher the bars and the deeper the pools become; and so far is this from facilitating the discharge, that, in the language of the Secretary of the Mississippi River Commission, "the effect of an approaching flood is to impede its own discharge, and the impediment outlasts the flood." An example of this action is found in the flood of 1858 at Columbus, Ky., where the river was leveed. The discharge of the river exceeded 1,100,000 cu. ft. per second, four times from December to June. The stages at which the river discharged this amount were: 29.5 ft., 32.5 ft., 33.5 ft., and 35.0 ft. on a rising stage, and 31.6 ft., 34.7 ft., 35.9 ft. and 36. 9 ft. on a falling stage.

If the successive differences between rising and falling stages at which the discharge was 1,100,000 cu. ft., be taken out for each rise we have, 2.1 feet, 2.2 feet, 2.4 feet and 1.9 feet, as the legitimate effect of the change from a rising to a falling condition.

If, however, we compare the first and last rising stages when the discharge was 1,100,000 cu. ft., we find that in June it required a stage 5.5 feet higher to discharge this water than it did the previous December. Making the same comparison on falling stage we find a difference of 5.3 feet. This was due to deterioration of channel caused by a building up of the bars or weirs, by a sufficient amount to raise the stage 5.5 feet in order to discharge the same amount.

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surveys to determine. It consists in having ordinary sized levees, such as are now built, which will confine the ordinary floods, with waste weirs at such points as offer the best facilities of discharge through the swamps, to let off the surplus waters without detriment to the levees and with the least possible damage to the lands. There are a great many natural outlets from the river back to the main drainage channels of the bottoms, which could be utilized in this way. This sort of outlet, however, is more like the spilling of the water over the bank, than like a crevasse in the levee. These weirs would have to be miles in extent so that the depth of overflow need not be more than two feet. This arrangement has been adopted on the Rhone with very satisfactory results.[10]

*The relation of levees to low water navigation* has already been trenched upon above in showing the effect of increased stages at time of high water, in building up the bars. What is wanted is the removal of the bars, and for this purpose the low water energy should be increased and the high water effect diminished. In other words, the extremes should be brought nearer together which is all included in the term equalization of volume. Any influence, therefore, which forces these extremes farther apart is hurtful. Levees tend to make high water higher, and therefore, they are an injury to navigation.[11]

Evidently it would be of no advantage to navigation if the river bed were uniformly lowered a hundred feet, provided the same irregularities remained in the matter of pool and shoal.

If ever the river should be regulated in width so that the discontinuous movement of sediment becomes inappreciable, then the stage may be increased to advantage. It is highly improbable that this ever will be done, and therefore the building of levees on the banks of the Mississippi River will never prove an aid to low water navigation. On the contrary they will always tend to produce a certain amount of damage.

[10] See paper by the writer on "Protection of Lower Mississippi Valley from overflow" in Journal of the Association of Engineering Societies, v. 3, p. 169.

[11] See paper by Robt. E. McMath on "Levees, — their Relation to River Physics," in Journal of the Association of Engineering Societies, v. 3, p. 43.

## Steam-engine practice in the United States in 1884. By J. C. Hoadley, C.E., Boston, Mass.[1]

Following the usual course of development which rules in all untrammelled, healthful industries, no less than in the works of nature, the steam-engine is daily becoming more and more differentiated, the better to adapt each special form to some particular purpose.

As the machinist's tools used in its construction are specialized and adapted each to a single class of operations, — their increased efficiency for a special purpose more than compensating for the limited range of their utility, — so the steam-engine itself, broadly considered, is continually developing new and useful varieties. At the same time, and as a consequence of the earnest study devoted to each variety, a parallel tendency to fixedness of type in each class is no less apparent than is the diversity of types.

Pumping-engines for public water-works, with a few large engines for manufacturing and mining purposes, constitute a class by themselves.

Engines for rolling-mills and general metallurgical purposes form a well-marked class.

Great lumber-manufacturing regions, like Maine and Michigan, have called into being a class of engines particularly adapted to saw-mills and wood-working machines.

Marine engines constitute an important class, of which steamboat and ferry-boat engines are one distinct variety, and engines of ships-of-war another.

Locomotives form a distinct class, subdivided into several varieties more or less differentiated, — passenger-engines, freight-engines, mountain-engines, shunting-engines, and various small engines for mining and other purposes.

[1] The stereotype plates of this paper were furnished by the author. — Editor.

The hoisting engine, the steam-crane, the steam-pump, the steam-blowing engine, the steam fire-engine, the portable and the semi-portable engine, the traction-engine, are, each and all, clearly marked varieties.

The steam-ploughing-engine, a type highly developed in England, is almost unknown in the United States.

Engines specially designed for driving dynamos, for electric lighting, may almost be said to constitute a class of the quick-running, or high-speed, group of engines.

Nearly all these classes of engines are in full course of development in the United States at this time, some much more advanced than others, but for the most part in a highly specialized form already, and rapidly taking on greater fixedness of type.

A complete and discriminating notice of all would require a voluminous treatise. The limits of this paper will admit only a few conspicuous examples of some of the leading types; and the time at command will compel a pretty close adherence to the observation and experience of the writer, with the risk of some lack of symmetry and proportion as a probable consequence, and of some apparent egotism.

### WATER-WORKS ENGINES.

This classification is rather arbitrary; since it is intended to include only compound engines of a certain type, and to cover certain Corliss and Leavitt engines not used for water-works.

Examples of these engines are to be found in the public water-works at Lowell, at Lynn, and at Lawrence, and at the sewage-pumping station, Boston, Mass.; at the water-works in Providence and Pawtucket, R.I.; at St. Louis, Mo.; and at Saratoga, N.Y.

Engines belonging to this class, although not used for pumping, are the great Centennial Corliss engine, now supplying power for the car-shops at Pullman, near Chicago, Ill.; and the Leavitt engine at the Calumet and Hecla copper-mine, at Calumet, Houghton County, Mich.

### LOWELL PUMPING-ENGINE.

This is a vertical, compound engine, having its steam-cylinders and air-pump located on one side of the beam-centre, and its pump and fly-wheel on the other side. The high-pressure cylinder is 36 inches in diameter, with a stroke of 5 feet $1\frac{5}{8}$ inches. The low-pressure cylinder, which is located at the extremity of the beam, has a diameter of 57 inches, with 8 feet stroke.

In volume swept through by the pistons, the two cylinders are to each other in the ratio of 1 to 3.9. The air-pump is 25 inches in diameter, with a stroke of 3 feet.

The water-pump, of the Thames-Ditton, or bucket-and-plunger variety, has a stroke of 6 feet, with 36 inches diameter of chamber and 25.45 inches diameter of plunger. The fly-wheel is 25 feet in diameter. The beam is double, and its top is 29 feet 1 inch above the floor of the engine-room.

The contract requirements were: 75,000,000 pounds raised 1 foot for each 100 pounds of coal burned in the boiler furnaces, — equal to 2.64 pounds of coal per dynamic horse-power per hour, — and a capacity of 5,000,000 Winchester gallons (of 231 cubic inches each) in 24 hours, when making 11¾ double strokes per minute.

It can be safely and conveniently run at velocities ranging from 5 to 16 revolutions of the fly-wheel per minute. The actual, or static head, is 159 feet; and the virtual, or dynamic head, when the engine is making 9 revolutions per minute, is 161 feet.

This engine was tested, for duty and capacity, by a board of experts, consisting of Mr. James B. Francis, Mr. William E. Worthen, and the writer, in July, 1873, by a run of 80 consecutive hours; and gave a duty of 93,002,272 foot-pounds per 100 pounds of coal burned, and 191.8 mean indicated horse-power, with a mean consumption of 351 pounds of coal per hour, equal to 1.83 pounds of coal per indicated horse-power and per hour.

This engine was constructed by Henry G. Morris of Philadelphia.

Its subsequent performance has been still better. During 10 years and 4 months, from Sept. 1, 1873, to Dec. 31, 1883, the duty in foot-pounds per 100 pounds of coal burned for pumping, without deduction for ashes or clinkers, ranged between the annual mean of 108,699,620 and 89,739,070, with a general mean of 98,092,883.

During 5 consecutive years, 1875–1879, the mean duty on the same basis was 104,155,452.

During 9 years, 1875–1883, the duty in foot-pounds per 100 pounds of coal burned for all purposes, including warming the engine-house when not pumping, without deduction for ashes or clinkers, ranged between the annual mean of 72,925,000 and 78,757,528, with a general mean of 77,017,984.

### PUMPING-ENGINE, LYNN WATER-WORKS.

This engine, designed by Mr. E. D. Leavitt, jun., and built by I. P. Morris & Co. of Philadelphia, in 1873, presents some features then quite novel, but since often repeated.

and drops this matter on the succeeding wide shoal. That is, any influence towards a temporary adjustment of the river's bed to a high water discharge is an influence which is adding to the heights of all the sand bars on the river. The greater the stage, the higher the bars and the deeper the pools become; and so far is this from facilitating the discharge, that, in the language of the Secretary of the Mississippi River Commission, "the effect of an approaching flood is to impede its own discharge, and the impediment outlasts the flood." An example of this action is found in the flood of 1858 at Columbus, Ky., where the river was leveed. The discharge of the river exceeded 1,100,000 cu. ft. per second, four times from December to June. The stages at which the river discharged this amount were: 29.5 ft., 32.5 ft., 33.5 ft., and 35.0 ft. on a rising stage, and 31.6 ft., 34.7 ft., 35.9 ft. and 36. 9 ft. on a falling stage.

If the successive differences between rising and falling stages at which the discharge was 1,100,000 cu. ft., be taken out for each rise we have, 2.1 feet, 2.2 feet, 2.4 feet and 1.9 feet, as the legitimate effect of the change from a rising to a falling condition.

If, however, we compare the first and last rising stages when the discharge was 1,100,000 cu. ft., we find that in June it required a stage 5.5 feet higher to discharge this water than it did the previous December. Making the same comparison on falling stage we find a difference of 5.3 feet. This was due to deterioration of channel caused by a building up of the bars or weirs, by a sufficient amount to raise the stage 5.5 feet in order to discharge the same amount.

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dimensions, as will appear by the following table. Two of these engines are placed side by side, with a shaft and fly-wheel in common, so that they may be used singly or both together.

## I.

### TABLE OF DIMENSIONS: ENGINES.

Diameters: —

| | |
|---|---|
| High-pressure cylinders, inches | 18 |
| Low-pressure cylinders, inches | 38 |
| Piston-rod, high-pressure, inches | 3.5 |
| Piston-rod, low-pressure, inches | 4 |
| Air-pump, inches | 15 |
| Main water-pump, barrel, inches | 26.125 |
| Main water-pump, plunger, inches | 18.5 |
| Pump plunger-rod, inches | 4.5 |
| Bottom and supplementary valves outside of main seat, inches | 15.75 |
| The same inside of main seat, inches | 12.5 |
| Bucket valves outside of lower seat, inches | 22 |
| The same inside of upper seat, inches | 15 |
| Air-chamber, inches | 54 |
| Fly-wheel, feet | 30 |

Length of stroke: —

| | |
|---|---|
| Steam and water pistons, feet | 8 |
| Air-pump, inches | 28 |
| Distance between end-centres of beam, feet | 16.5 |

Lead of valves: —

| | |
|---|---|
| High-pressure admission valves, inches | 0 |
| High-pressure exhaust valves, inches | $\frac{1}{16}$ |
| Low-pressure admission valves, inches | $\frac{1}{16}$ |
| Low-pressure exhaust, top, inches | $3\frac{5}{16}$ |
| Low-pressure exhaust, bottom, inches | $4\frac{3}{16}$ |

Cushion: —

| | |
|---|---|
| High-pressure exhaust, top, inches | $14\frac{1}{4}$ |
| High-pressure exhaust, bottom, inches | $14\frac{3}{4}$ |
| Low-pressure exhaust, top, inches | $4\frac{1}{2}$ |
| Low-pressure exhaust, bottom, inches | $8\frac{1}{4}$ |

Volume of clearance and waste-room, in terms of volume swept through by the pistons: —

| | |
|---|---|
| High-pressure, top | .0256 |
| High-pressure, bottom | .0231 |
| Low-pressure, top | .0154 |
| Low-pressure, bottom | .0182 |

| | |
|---|---|
| Connecting-pipe between cylinders, referred to the high-pressure cylinder, | .0992 |
| Weight of fly-wheel (16 tons), pounds | 35,900 |
| Weight of beam, pins, and counter balance (14½ tons), pounds | 25,700 |
| Weight of high-pressure piston, rod, and connections, pounds | 2,575 |
| Weight of low-pressure piston and connections, pounds | 4,175 |
| Weight of air-pump piston and connections, pounds | 1,800 |
| Weight of pump plunger-bucket, pounds | 7,200 |
| Weight of main connecting-rod, beam to crank, pounds | 3,800 |
| Total weight of reciprocating parts, pounds | 45,250 |

Boilers: —

| | |
|---|---|
| Number of boilers | 2 |
| Length of shell, feet | 25.46 |
| Length of mid-feather, feet | 12 |
| Length of combustion-chamber, feet | 3 |
| Length of tubes, feet | 10 |
| Diameter of tubes, inside, inches | 3 |
| Number of tubes | 80 |
| Diameter of cylindrical shell, feet | 5.25 |
| Width of each fire-grate, inches | 34 |
| Length of each grate, inches | 60 |
| Number of grates | 4 |
| Total fire-grate area, square feet | 56.67 |
| Length of steam-drum for both boilers, feet | 12.5 |
| Diameter of steam-drum, inches | 24 |

The boilers were designed expressly for this engine. They have interior fire-boxes, divided by a "mid-feather" into two furnaces in each boiler; this mid-feather extends back 12 feet, beyond which a combustion-chamber extends 3 feet to the flue-sheet.

The gaseous products of combustion pass from the combustion-chamber through 80 flues 10 feet in length and 3 inches in diameter inside, and return beneath the boiler nearly to the ash-pit, where they pass downward, laterally, into a depressed flue leading to the chimney.

A trial of this engine for duty and capacity was made May 2, to May 6, 1876, by a board of experts, consisting of William E. Worthen, Joseph P. Davis, and the writer, with an adequate number of trained assistants.

The run of one engine by itself was divided into two periods of 22 hours and 35 hours respectively, with an interval of one hour and 34 minutes, caused by the accidental blowing-out of a pipe for attaching an indicator to the pump-chambers.

A run of 34 hours was then made with the engines coupled together.

Weir measurements were made of the quantity of water delivered

to the reservoir; which showed a loss of action in the pumps, from their estimated capacity, of 5.2 per cent.

The contract requirements were, for capacity, 2,000,000 gallons (of 231 cubic inches) in 10 hours, for each engine; and, for duty, 95,000,000 foot-pounds for every 100 pounds of best Cumberland (semi-bituminous) coal consumed in the furnaces.

In determining the duty, the quantity of water pumped was to be ascertained by adding to the quantity measured at the weir, 5 per cent of the same for loss of action in the pump, — a quantity almost exactly coincident with the observed difference between the estimated and measured delivery.

The resistance, or "lift," was to be ascertained by adding to the mean pressure observed in the rising main, at a point within 100 feet of the engine-house, the pressure corresponding to a water column equal in height to the vertical distance from the mean level of the water in the pump-well to the level of the pressure-gauge on the rising main, increased by 1 pound to compensate for resistances within the suction-pipe and pump. So determined, the dynamic lift was from 165 to 174 feet.

The force-main was 30 inches in diameter, and 4,900 feet long; with branches from engines to main, 24 inches in diameter and 75 feet long.

During the first and second tests, when one engine was run singly, both boilers were used; but the fire-grate area was reduced, by means of a wall of fire-brick built on the grates at the rear end, to an aggregate area of 47 square feet.

When both engines were run, during the third test, the bricks were removed, and the aggregate area of the fire-grates was 56.67 square feet.

Since the steam pressure and the speed of the engine were nearly constant, the state of the fire at any given time could be well inferred from the rate of firing during a certain period before and after that time, by inspection of a chart or diagram, on which intervals of time between firings were represented by abscissæ, and quantities of coal fired by ordinates; and the beginning and ending of the periods, of 22 hours and 35 hours for one engine, and of 34 hours for both engines, were determined in this manner.

The water condensed from steam of boiler-pressure in the jackets of both cylinders of one engine was found, by measurement after the test was over, to be 338.85 pounds per hour, equivalent to the evaporation from feed-water temperature of 100° Fah. under mean

boiler-pressure, of 271.08 pounds. This is about 10 per cent of the quantity which passed out per hour as exhaust steam.

The rate of combustion and evaporation is exhibited in the following table of the performance of the boilers.

TABLE II.

PERFORMANCE OF THE BOILERS.

| Number of Test. | Duration of Test. | Coal Burned. | | Water Evaporated. | | | Water evaporated from 100° Fah. per Pound of Coal. | |
|---|---|---|---|---|---|---|---|---|
| | | During Test. | Per Square Foot of Grate per Hour. | Passing through Cylinders. | Passing through Jackets. | Total. | Through Cylinders. | Total. |
| | hours. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 1 | 22 | 7,266 | 7.03 | 60,370 | 5,964 | 66,334 | 8.30 | 9.13 |
| 2 | 35 | 11,630 | 7.07 | 96,540 | 9,488 | 106,028 | 8.31 | 9.12 |
| 3 | 34 | 18,411 | 9.56 | 160,658 | 18,433 | 179,091 | 8.73 | 9.73 |

*Duty.*

The "lift," as determined according to the terms of the contract, was, during the 22 hours run, 75.96 × 2.31 = 175.47 feet.

The weight of a gallon (231 cubic inches) of water, estimated from the determination of its specific gravity by Mr. Hasenclever, was 8.38 pounds.

The quantity of water delivered over the weir into the reservoir was 4,527,340 gallons, which, increased by 5 per cent of itself for loss of action of the pump, becomes 4,753,707 gallons lifted by the engine. This multiplied by the weight of a gallon, 4,753,707 × 8.38 = 39,836,064 pounds lifted 175.47 feet; and 39,836,064 × 175.47 = 6,990,034,150 foot-pounds raised by the consumption of 7,266 pounds of coal; and 6,990,034,150 ÷ 7,266 = 962,019 foot-pounds, as the duty of one pound of coal, equal to 96,201,900 foot-pounds per 100 pounds of coal.

Estimated in the same manner, the duty during the 35 hours' run was 96,177,600 foot-pounds, and for the whole 57 hours the mean was 96,186,979 foot-pounds per 100 pounds of coal. During the 34 hours' run with the two engines coupled together, the duty was 98,261,700 foot-pounds per 100 pounds of coal.

This shows that the performance of 1 dynamic horse-power 1

hour required the consumption of 2.06 pounds of coal in the same time for the single engine. Estimated per indicated horse-power, by the mean of indicator diagrams taken, the consumption was 1.69 pounds per 1 horse-power per hour.

It therefore appears that the work done by the engine, as measured by the dynamic effect upon the water lifted, was 82 per cent of the indicated power; and that the loss by frictions of engine and pump was 18 per cent.

It appears from the reports of the Lawrence Water Board, that for the 5 years 1879–1883, the performance was still better. The mean for the 5 years is as follows: Duty in foot-pounds, calculated on all the coal used for all purposes, including warming the engine-house, and without the addition for frictions in suction-pipe and pump of the 1 pound per square inch allowed at the test, and without deduction for ashes and residue, was, per 100 pounds of coal, 98,318,516 foot-pounds.

During the same period of 5 years, the duty calculated on all the coal used for starting and banking fires and for pumping, but not for warming the engine-house when the pumps were not running, without addition for frictions in suction-pipe and pump, and without deduction for ashes or residue, was, per 100 pounds of coal consumed, 102,120,127 foot-pounds.

An independent and impartial test of this engine was made in July, 1879, by Mr. Richard H. Buel of Mr. Park Benjamin's scientific expert office, New York, preparatory to inserting a description of the engine and an account of its performance in a new edition of Appleton's Cyclopædia of Applied Mechanics, then in preparation under the editorship of Mr. Park Benjamin.

This test was reported with great minuteness and clearness, and bears evident marks of intelligent care.

The duty so ascertained, without addition for frictions in suction-pipe and pump, and without deduction for ashes and residue, was, in foot-pounds for every 100 pounds of coal consumed, 111,548,925.

### PUMPING-ENGINES AT THE SEWAGE-PUMPING STATION IN BOSTON.

These two engines, desgined by Mr. E. D. Leavitt, jun., are compound beam-and-fly-wheel engines, with vertical inverted cylinders, having their pistons connected to opposite ends of the beam, and moving in opposite directions, each giving motion by a prolongation of its piston-rod to the plunger of a single-acting pump below it.

The cylinder diameters are: —

High-pressure, 25.5 inches; low-pressure, 52 inches; pump-plunger, 48 inches; and the stroke, common to all, is 9 feet.

Both cylinders are thoroughly steam-jacketed on sides and ends; and the exhaust steam from the high-pressure cylinder passes, on its way to the low-pressure cylinder, through re-heaters filled with tubes containing high-pressure steam.

The boilers and the engines are designed for steam of 100 pounds pressure per square inch above the atmosphere. The engines are intended to run 12 revolutions per minute. They have been in operation since Jan. 1, 1884; and during 17 weeks from Jan. 26 to May 24, pumped a daily mean quantity equal to 28,466,314 Winchester gallons against a mean head of 35 to 36 feet.

The daily consumption of coal, with 15.59 per cent refuse, was 15,590 pounds; but an unknown quantity of steam was used to keep reserve Worthington pumps in running order, and to do some pumping with them, and for other purposes, so that the data are too inexact to afford a basis for the calculation of duty. It is to be hoped that the city of Boston may contribute the results of a well-conducted test of these important engines to engineering science, in a manner to commend itself to general confidence.

### "SUPERIOR."

A hoisting-engine designed by Mr. E. D. Leavitt, jun., for the Calumet and Hecla copper-mine at Calumet, Houghton County, Mich., and built by the I. P. Morris Company, Philadelphia, in 1881, bears the above significant name.

This fine engine forms the subject of a paper by its designer, read before the American Society of Mechanical Engineers at the Hartford meeting in May, 1881; published in the Transactions of the Society, vol. ii. pp. 106–121; and republished, with all the illustrations, in the American Machinist, vol. iv., No. 26, June 25, 1881.

Only the briefest summary of its dimensions and constructive features will be here given.

The cylinders are respectively 40 and 70 inches in diameter, vertical, 9 feet apart between centres, and have each a stroke of 6 feet, which, with a speed of 60 revolutions per minute, gives a piston speed of 720 feet per minute.

The normal boiler-pressure is 135 pounds per square inch above atmosphere, equal to 10.19 atmospheres absolute, with initial pressure very little less, full admission to the point of cut-off, and prompt suppression.

The valves are gridiron slides, four for each cylinder, with 16 ports each, and have only one inch travel. The admission valves of the high-pressure cylinder are under the control of a sensitive Porter governor, but are actuated by the piston of a small subsidiary steam-engine, automatically adjusted by the governor, giving a range of admission of from 0 to .6 of stroke.

The low-pressure inlet-valves are set to close at 35 inches, — equal to 48.61 per cent of stroke. All the cams for moving the valves are placed on a cam-shaft carried in brackets secured to the side of the main bed-plate, and also supported from the engine foundation, and driven by mitre-gears from the crank-shaft, which is of hammered steel, 18 inches in diameter, and 45 feet long, with journals 32 inches long.

The crank-pin journal is 18 inches in diameter, and 24 inches long. Two re-heaters, one at each end, are placed between the cylinders, each having 941 brass tubes $\frac{5}{8}$ inch diameter, $\frac{1}{32}$ inch in thickness, and 60 inches long, presenting, therefore, an aggregate tube-surface of 1,540 square feet, equal to 14 per cent of the heating surface of the boilers.

These tubes are filled with steam of boiler-pressure, and the passing steam is so guided among them by deflectors as to make all the tube-surface effective.

Steam is supplied by five locomotive boilers, presenting in the aggregate 260 square feet of fire-grate area, and 11,000 square feet of water-heating surface, — a ratio of 42.3 to 1; and 2.34 square feet of heating-surface for each indicated horse-power at the maximum, 4,700 indicated horse-power, when cutting off at half stroke in the high-pressure cylinder; an effort only required occasionally for short periods, when all the skips are at the bottom of the mine together.

The boilers are 33.4 feet in extreme length, 110.5 inches wide at bottom of fire-box, 96.56 inches high over the fire-box, and 84 inches in diameter inside of the barrel, which has double and treble riveted, double-fished butt-joints.

Each boiler has two furnaces 8 feet long, 4 feet wide, and 5.52 feet high above base ring; a combustion-chamber 2.92 feet long in rear of each furnace, and a common combustion-chamber for the two furnaces 4.08 feet long to the tube-sheet; and 118 iron tubes 3.5 inches in diameter outside, and 18 feet long between the tube-sheets.

The plates are all of best open-hearth steel, $\frac{5}{16}$ inch thick in the furnaces, and $\frac{6}{16}$ inch in the barrel and fire-box casing.

There is no brick setting, but the outside is carefully clothed with non-conducting materials. There has been no regular test, save the test of daily performance, which is highly satisfactory. Indicator diagrams taken in regular work are very beautiful.

### PUMPING-ENGINE, PAWTUCKET, R.I.

This engine, designed by Mr. George H. Corliss, and built by the Corliss Steam-Engine Company, Providence, is a horizontal, compound, receiver engine, with its cylinders placed side by side, but separated by the length of the crank-shaft, as in ordinary double or two-cylinder engines.

The cylinders are respectively 15 and 30 inches in diameter, and the stroke, common to both, is 30 inches. The pump-pistons have a stroke also of 30 inches, and a diameter of 10.52 inches, and are keyed upon prolongations of the piston-rods of the engines, which extend through the pumps to cross-heads running in forked slides cast in one piece with the pump-heads farthest from the steam cylinders.

The cylinders are sustained by hollow legs at their ends, which mask the steam and exhaust pipes. The pump-barrels are enclosed in firm rectangular plinths, which are securely connected, by ties and struts, with the steam-cylinders.

Rectangular dies, resting on these plinths and firmly secured to them, serve as valve-casings, and air-chambers for the pumps, and as supports for the crank-shaft boxes, the centre of the crank-shaft being 9 feet 8 inches above the floor of the engine-room. Short connecting-rods, or front-links, 6 feet 2 inches in length, which extend from the cross-heads to wrist-pins in the forked upper extremities of cast-iron rockers, give these rockers a reciprocating motion upon centres 6 feet 2 inches below.

These rockers spread out at the upper end to a width sufficient to take in two pins 5 feet apart between centres, to each of which two wrought-iron rods are secured, the four rods of each set meeting at their upper ends, where they are united by a pin which serves as the wrist-pin for one end of a connecting-rod 12 feet 6 inches long, extending to the wrist-pin of a crank on the fly-wheel shaft.

Each set of four rods, in connection with the cast-iron rocker at their base, forms a rigid extension of the rocker upwards to just twice the height of the cast-iron portion, so that the two cranks on the fly-wheel shaft, which are set at right angles, are 30 inches in length, equal to the stroke of the steam and water pistons.

A strong brace extends downward from each die, in a direct line

from the crank-shaft, at an angle of 45 degrees, to the sole-plate near the supports for the lower ends of the rockers.

The fly-wheel, 18 feet in diameter, running entirely above the floor, has a flat face 12 inches wide and 2 inches thick, with a central rib 5 inches wide, and is properly very light, as it has very little to do.

All parts of the steam-cylinders, covers, and valve-chests, are steam-jacketed; but live steam is not introduced into the pistons. Normal boiler-pressure is 125 pounds per square inch above the atmosphere, and expansion in both cylinders is about twenty-fold.

Water resulting from condensation in the jacket of the high-pressure cylinder is returned directly to the boilers; and the drainage from the receiver, including that from the jacket of the low-pressure cylinder, is re-evaporated and superheated by passing through tubular re-heaters in the smoke-flues, and returned as superheated steam to the receiver. The valves and valve-gears are all of Mr. Corliss's well-known construction.

Steam is furnished by three of Mr. Corliss's patent upright tubular boilers, each 4 feet in diameter and 14 feet long, of the same form and arrangement as those which furnished steam for the Corliss engine at the Centennial Exhibition in 1876.

Each boiler has 560 square feet of heating-surface, and 19.63 square feet of fire-grate area. The escaping gases of combustion pass for a considerable distance through tubes surrounded by steam, and doubtless cause a good deal of superheating.

Two distinct tests of this engine were made by Mr. Walter H. Sears, chief engineer of the Pawtucket Water-works, and Mr. Isaac R. Scott, president of the water board of Waltham, Mass.; one of 10 hours per day during two weeks, Tuesday, Aug. 6, to Monday, Aug. 19, 1878, excluding the two intervening Sundays, Aug. 11 and 18.

The total run was therefore 120 hours, in 12 periods of 10 hours each, with 9 intervals of 14 hours each, and 2 of 36 hours each. The wood used for kindling fires, 2,126.5 pounds (89 pounds each day to each boiler), was estimated as coal at 45 per cent of its weight, equal to 957 pounds of coal, which added to 6,521 pounds of coal used in starting fires (271 pounds per day, per boiler) makes 7,478 pounds of coal, equal to 311 pounds of coal per day for each boiler, principally consumed by reason of the intervals when the engine was at rest.

The coal used for pumping was 26,598.5 pounds; and all the coal used for starting fires and pumping, including the estimated coal-

value of the wood, was 34,076.5 pounds, of which 22 per cent was used in starting fires. (Only two boilers were used in this test.)

The duty, calculated upon the capacity of the pumps, the mean resistance, and the whole number of pump-strokes for each 100 pounds of coal consumed, without deduction for ashes and residue, was 104,357,654 foot-pounds.

A weir measurement, made Aug. 28, 1878, revealed a loss of action of 4.12 per cent, which was subsequently much reduced by a change of valves.

The other test, of 24 consecutive hours' duration, begun Oct. 3, 1878, at 9 o'clock A.M., gave a duty, calculated on the capacity, mean resistance, and number of strokes of the pump, of 133,522,060 foot-pounds for each 100 pounds of coal burned while pumping, without deduction for ashes or residue. In this test, all three boilers were used.

These results, which I see no reason to question, are the more remarkable when the small size of the engine, and its low speed, are taken into consideration. The space swept through by the piston at each revolution, or double stroke, is, for the high-pressure cylinder, only 6 cubic feet, — for both cylinders, only 30 cubic feet; and at the normal speed, 52 revolutions per minute (the actual speed at the tests was 51.8), the velocity of the piston was only 260 feet per minute.

Sets of diagrams from these cylinders show close conformity to normal action of the highly expanded steam.

Confirmation of the accuracy of the results above given is to be found in the fourth annual report of the water commissioners and superintendent of water-works of the town of Pawtucket, dated Feb. 1, 1884. A table is there given in detail of the performance of this engine for each of the twelve months ending Dec. 31, 1883, of which the sums and means for the year are subjoined.

| | |
|---|---|
| Number of days when pumping was done, per month, 23.1 | 277.2 |
| Total number of hours' pumping | 3,852 h., 49 m. |
| Hours and minutes per month | 321 h., 4 m. |
| Hours and minutes per day | 13 h., 54 m. |
| Total number of revolutions | 10,698,618 |
| Revolutions per month | 891,551 |
| Revolutions per day | 38,623 |
| Revolutions per minute | 46.31 |
| Coal consumed: pounds, starting fires | 181,800 |
| Banking fires | 72,300 |
| Starting and banking fires | 254,100 |
| Warming engine-house | 18,941 |

| | |
|---|---|
| Consumed when not pumping | 273,041 |
| Consumed in pumping | 660,865 |
| Total coal consumed | 933,906 |
| Total number of gallons pumped in 12 months | 441,061,225 |
| Mean head in feet against the pump, no allowance for frictions in suction | 264.19 |
| Mean duty in pounds of water raised 1 foot per 100 pounds of coal used for all purposes, no deduction for ashes and residue, | 106,203,760 |
| Mean duty in pounds of water raised 1 foot per 100 pounds of coal used for all purposes except warming, no deduction for ashes and residue | 108,402,320 |

### HORIZONTAL COMPOUND ENGINE.

In the Nourse Mill of the Social Manufacturing Company, Woonsocket, R.I.

This engine, designed by Mr. George H. Corliss, and built by the Corliss Steam Engine Company under a guaranty to run a year with a consumption of no more than 1.75 pounds of coal per horse-power and per hour, — all the coal fired during the year for supplying this engine with steam being divided by the mean indicated horse-power and by the number of hours' run of the engine, — is a fine example of its class.

It is a tandem, receiver, double engine, combining the effort of the two pair of pistons upon a single fly-wheel shaft with cranks set "quartering." The cylinder diameters are respectively 20 and 36 inches. The length of stroke common to both is 6 feet, and there is a space of about 4 feet between the end-casings of the two cylinders, to give access to the low-pressure piston.

The connecting-rod is 18 feet in length, so that the entire engine, from the centre of crank-shaft to the outer end of the high-pressure cylinder, occupies a length of about 42 feet. The fly-wheel is 30 feet in diameter, and has a rim 110 inches wide with four belt-faces. The weight of the fly-wheel, crank-shaft, cranks, and eccentrics, is about 54.5 tons, say 120,000 pounds.

The normal speed is 57 revolutions per minute; so that the velocity of the pistons is 684 feet per minute, and that of the belt 92 feet more than a mile per minute.

The weight of the reciprocating parts is 7,711 pounds, and at normal speed their momentum is equal to 19.38 pounds pressure per square inch on the area of both pistons.

The normal boiler-pressure is 110 pounds per square inch above the atmosphere; and about 8 pounds pressure above atmosphere is carried in the receiver.

Both cylinders are steam-jacketed all around their sides and ends, — the high-pressure cylinder directly from the boiler, the low-pressure from the receiver; and in both, steam is admitted by the induction-valves to the cylinders from the jackets.

The cylinders are supported by hollow legs at each end, which mask the descending exhaust-pipes. Each cylinder has a projecting zone around it in the middle of its length, about 14 inches, lengthwise of the cylinder, projecting about 7.5 inches all around beyond the jacket-casing, which serves the double purpose of providing for unequal expansion, and of taking in steam and drawing out water conveniently.

Steam from the boilers is admitted to the jacket of the high-pressure cylinder at the top; and water formed by the condensation of steam in this jacket is drawn out at the bottom, and pumped directly back to the boilers.

It is obvious, from the construction and setting of the boilers (hereafter described), that the steam, even on entering the jacket, may be to some extent superheated: but a considerable quantity must be condensed in this jacket; since the expansion in this cylinder is about 5-fold, and the mean internal temperature necessarily considerably below that of initial steam.

The exhaust-pipes from the high-pressure cylinder, with a pipe about 12 inches in diameter which receives the steam from these pipes, and conducts it to the middle of the length of the low-pressure cylinder, where it enters the jacket of this cylinder at the bottom, and this jacket itself, constitute the receiver, in which the pressure varies but slightly.

The expansion in the low-pressure cylinder is almost 4-fold, so that the whole expansion in both cylinders is 18 to 20 fold. Steam for warming the mill, for water-pots in the weaving-room, and for all other purposes except for the slashers (for which steam is taken directly from the boilers), is drawn from the receiver, so that less steam enters the second cylinder than is discharged from the first: as it is, however, the effective power developed in the two cylinders is very nearly equal.

The drainage from the receiver, which, it will be remembered, includes the water formed by condensation in the jacket of the low-pressure cylinder, is pumped through a set of tubular heaters at the top of the descending flues from the boilers, where the escaping gases are hottest; and returns to the receiver as steam, probably considerably superheated.

Similar tubular heaters, located immediately under those last

mentioned, receive the feed-water on its way to the boilers, and raise its temperature, probably to that corresponding to boiler-pressure. Feed-water is supplied in part by drainage from the mill, and, for the rest, from the hot-well.

At present, one engine only is in place, and that is exerting only about 400 indicated horse-power (four-fifths of its normal load); but the demand for power is gradually increasing, as new machinery is started. Of the nine boilers ultimately to be erected, — eight for regular use, and one to be held in reserve, — only four are now set up. These are vertical, 64 inches in diameter, and 14 feet in height.

The hot gases of combustion fill a space around the shell of the boiler, between it and the brickwork, for a height of 5 feet, but without direct outlet. They pass off through 84 flues, 3 inches in external diameter and 14 feet long, into a smoke-box on top of the boiler, whence they flow rearward to, and downward through, first the re-heater for the drainage of the receiver, then the feed-water heater, and finally down through a vertical brick flue to a horizontal flue underground, and so off to the chimney.

The brick-work around the cylindrical shell of the boiler is incased in plate-iron for a height of 10 feet 6 inches from the floor, and by a cast-iron cornice for another foot, which cuts off infiltration of air; and the shell of the boiler above the cornice is plastered with some heat-intercepting material.

The fire-grates, 76 inches in diameter, have an area, in the aggregate, for the four boilers, of 126 square feet; and at the rate of 1.75 pounds of coal per indicated horse-power per hour, to supply steam for 500 horse-power will require a rate of combustion equal to 7.0 pounds per square foot of fire-grate area and per hour.

The ratio of water-heating surface to fire-grate area is about 24 to 1; that of steam-heating surface to fire-grate area, about 9.3 to 1; and the total, about 33.3 to 1: but the relative proportions of water and steam-heating surface will depend on the height at which water is carried. The gases evidently go to the re-heaters very hot, and may not be very effectually cooled on passing to the chimney.

A set of diagrams was taken from this engine by the writer, May 22, 1884; and a set taken April 9, by Mr. John T. Henthorne of the Corliss Steam-Engine Company, has since been furnished by him. When the first set was taken, no steam was diverted at the receiver from the low-pressure cylinder. A little was so diverted when the second set was taken, May 22.

TABLE

OF THE QUANTITY OF STEAM FOUND AT VARIOUS PARTS OF STROKE IN TWO SETS OF DIAGRAMS.

| Taken April 9, 1884, by J. T. Henthorne. Power: 394.32 indicated horse-power. | | Taken May 22, 1884, by J. C. Hoadley. Power: 395.00 indicated horse-power. | |
|---|---|---|---|
| Parts of Stroke. | Pounds of Steam. | Parts of Stroke. | Pounds of Steam. |
| Cut-off . . . 0.150 | 9.73 | Cut-off . . . 0.178 | 9.97 |
| .59 | 11.22 | .625 | 11.32 |
| .74 | 11.40 | .75 | 11.35 |
| End . . . . 1.00 | 11.47 | End . . . . 1.00 | 11.35 |
| End L. P. Cylinder. | 10.40 | End L. P. Cylinder. | 10.57 |

To the visible quantity must be added the quantity condensed by conversion of its heat of vaporization into work, and the quantity condensed in the jacket of the high-pressure cylinder; and doubtless an unknown quantity resulting from internal surface condensation, which must make the total quantity about 16 to 16.5 pounds per horse-power per hour, quite within the reasonable duty of 1.75 pounds of coal.

A preliminary test of a week's run was made during the week ending April 12, 1884; from a report of which, issued by the Corliss Steam-Engine Company, the following abstract is taken.

Fires were started on clean grates on Monday morning, April 7, 1884.

| | |
|---|---|
| Wood used for kindling fires, 3,344 pounds; equivalent at 40 per cent to coal, pounds | 1,337 |
| Coal used for starting fires, pounds | 18,350 |
| Coal for running, pounds | 27,722 |
| Total quantity of coal, and coal value of wood, pounds | 47,409 |
| Running-time from opening to closing screw-valve, hours | 67 |
| Mean indicated horse-power from 364 cards (1 in 11 minutes) | 407.28 |
| Mean speed, revolutions per minute | 56.62 |

Of the 6,777 pounds of coal on Saturday, April 12, 3,330 pounds weight was picked out of the cinders from the previous days. Omitting the wood, the coal used was a little less than 1.69 pounds per horse-power per hour.

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vision of Mr. George W. Weeks, agent of the mills, a member of the American Society of Mechanical Engineers, well known to the writer, who vouches for his candor and intelligence.

This is what is usually called a "double engine," that is, a pair of engines, right and left hand, with a fly-wheel and shaft in common, and cranks set at right angles. The dimensions are: diameter of cylinders, 26 inches; length of stroke, 5 feet; fly-wheel, 30 feet in diameter, 6 feet belt-face; air-pump, 34 inches in diameter, 12 inches stroke.

The cylinders are not steam-jacketed. Steam is supplied by five return-tubular, externally fired horizontal boilers, 60 inches in diameter outside of the smaller courses, with 76 flues, 3.25 inches outside diameter, and 19 feet 8 inches long; set with overhanging smoke-box, the front flue-sheets being about in the plane of the arch-fronts.

| | |
|---|---|
| Heating-surface . . . . . | .1345 × 5 = 6725 square feet |
| Fire-grate area . . . . . | 28.5 × 5 = 142.5 square feet |
| Ratio of heating-surface to fire-grate area . . . . . | 47 to 1 |
| Steam-pressure in boiler, in pounds per square inch above atmosphere, | 87. |
| Vacuum, in pounds per square inch below atmosphere . . . . . | 13.02 |
| Mean speed of engine in revolutions per minute . . . . . | 52.71 |
| Mean piston-speed, feet per minute . . . . . | 527.1 |
| Clearance, in terms of volume swept through by the piston . . . . | .0239 |

The test was continued four days, and sets of diagrams were taken six times each day, three times in the forenoon and three in the afternoon. The first set was taken soon after starting the engine, at 6.50 to 6.58 A.M.

The second set was taken between 8.06 and 9.34 A.M.; the third, between 9.48 and 11.12; the fourth, between 2.02 and 3.06 P.M.; the fifth, between 2.48 and 3.44; and the sixth, between 4.03 and 4.48.

The least power observed was 641.90 horse-power, the greatest 703.35, a range of only about 9 per cent. The means for the respective days were: —

*Horse-power.*

| | |
|---|---|
| First day . . . . . | 684.13 |
| Second day . . . . . | 666.92 |
| Third day . . . . . | 663.51 |
| Fourth day . . . . . | 669.09 |
| Mean of all . . . . . | 670.91 |

There were burned under the boilers from 6 o'clock of the evening preceding the first day of the test, to 6 o'clock P.M. of the last day, when the test ended, 57,000 pounds of coal, which yielded 4,600

pounds of dry ashes and refuse, leaving 52,400 pounds of combustible.

Ratio of ash to coal, 8.07 per cent. The hours run were 11 hours each day, 44 in all.

| | |
|---|---|
| Coal per hour, pounds | 1,295.45 |
| Coal per hour, and per indicated horse-power, pounds | 1.93 |
| Combustible per hour, pounds | 1,190.91 |
| Combustible per hour, and per indicated horse-power, pounds | 1.77 |

A test of the evaporative efficiency of the boilers and coal, not simultaneous with the engine-test, but some time before, gave an actual evaporation of 10.58 pounds of water per pound of coal burned; or, corrected, by estimate, for water blown off during the day, and water pumped in at night, 10.07 pounds.

Computed from the indicator-cards, the quantity of water "visible" as steam was equal to 8.67 pounds for each pound of coal burned during the test, which would indicate the presence of 13.9 per cent of the feed-water in the liquid form in the cylinder.

The number of diagrams taken may be thought too few to give assurance of the true mean of the power during the 44-hours' run; but if the smallest mean be taken, that for the third day (663.51 indicated horse-power), the coal consumption per hour and per indicated horse-power becomes 1.95 pounds, against 1.89 pounds if the largest mean-power, that for the first day (684.13 indicated horse-power), be taken.

Again, if we take the smallest power observed during the four days, at 4.03 to 4.05 P.M. of the second day, 641.90 indicated horse-power, and compare the result with that obtained by using the largest observed power, at 9.31 to 9.34 A.M. of the first day, 703.35, we have respectively 2.02 and 1.84 pounds per indicated horse-power and per hour, each differing from the mean, 1.93, only 4.5 per cent.

Upon the basis of 10 pounds of water evaporated under actual conditions, for each pound of coal burned, we have 19.3 pounds of feed-water per indicated horse-power and per hour; and by the indicator cards, 16.73 pounds; so that, of the feed-water supplied to the boilers, 86.7 per cent was accounted for by the indicators, and 13.3 per cent was present as liquid water. (Published in "Cotton, Wool, and Iron," Boston, Mass., Feb. 9–16, 1884.)

During the year ending April 26, 1884, the coal burned in the furnaces of these boilers, supplying steam for all purposes, including 3,070 hours actual running-time of this engine, at 670 indicated horse-power, as computed from numerous indicator diagrams, amounted to

1,967 tons, equal to 4,406,080 pounds, which gives 2.14 pounds of coal consumed in the mill, for all purposes, for each indicated horse-power exerted one hour.

It may be thought that too much space has been given to this test; but it is so good an example of valuable work within the reach of nearly all users of steam-engines, that it has been thought well to bring it to notice in this manner.

*The Putnam Machine Company*, Fitchburg, Mass., were among the earlier manufacturers of an excellent class of automatic cut-off, horizontal engines, of medium speed and moderate power.

Being well described in Tolhausen's Uhland, it will be unnecessary to describe them here. By the use of double-seated poppet-valves and an ingenious combination of cams and levers, the cut-off is controlled by the governor, and an excellent distribution of steam is effected, with satisfactory uniformity of speed.

The writer has occasionally tested an engine of this construction, 12-inch cylinder, 30-inch stroke, during a period of 17 years, and always found it tight, and in perfect order, almost without repairs.

This valve-gear is not well adapted to speeds higher than 90 or 100 revolutions per minute.

*Charles H. Brown & Co.*, also of Fitchburg, by means of gridiron slide valves, actuated by cams and levers, and detaching mechanism controlled by the governor, obtain very prompt and full admission, almost instantaneous cut-off, and free release, and produce indicator diagrams almost ideally perfect.

In point of mechanical execution and finish, the Brown engines are singularly beautiful, and in all the higher qualities of design and proportion they are excellent. This engine, also, is described in Tolhausen's Uhland.

*The Fitchburg Steam-engine Company*, also of Fitchburg, Mass., a newer enterprise, is now making an automatic cut-off engine of much higher order than the small vertical engines described in Tolhausen's Uhland.

They make a peculiar form of centrifugal governor placed on the crank-shaft; a kind of governor which has gained great favor within the last ten years, and assumed a multitude of forms. We shall again have occasion to speak of this governor.

In the form under notice, which is excellent, the eccentric is guided in its transverse motion across the shaft, by means of a sort

of parallel motion, consisting of two levers connected with ears on opposite sides of the eccentric-block, describing equal arcs in opposite directions; thus avoiding the guides used in some other forms, while preserving constant lead of valve. Weights attached to these levers exactly counterbalance the weight of the eccentric and its strap, and, in vertical engines, the weight of the valve-rod and connections also, in all positions, leaving the eccentric neutral under all the impulses of the governing mechanism. This consists of weights on arms pivoted to opposite sides of an incasing pulley, connected by rods to the balancing-arms already mentioned, acting centrifugally with a force proportioned to the rapidity of revolution, opposed by springs which act centripetally with a force proportioned to the compression produced by the revolving-weights.

These forces being properly adjusted, so as to be in equilibrium at normal speed, this speed will be maintained so long as the load and the mean effective pressure of steam in the cylinder remain relatively unaltered.

Any increase of load, with steam-pressure constant, will cause a corresponding diminution of velocity, and therefore of centrifugal force in the weights, and give a preponderance to the springs acting centripetally, so as to turn the eccentric to delay the cut-off, and so to increase the mean effective pressure. On the other hand, any diminution of load will give preponderance to the centrifugal force of the weights, and turn the eccentric so as to hasten the cut-off, and reduce the mean effective pressure.

When a single piston-valve is used, release and exhaust-closure are affected in the same sense as cut-off: with early cut-off, there is early release and early closure of the exhaust; and with later cut-off, both release and closure are retarded, as in a link-motion.

The single valve is used only in the smaller engines, especially in vertical engines. In larger, horizontal engines, from 9-inch diameter and 24-inch stroke to 24-inch diameter and 48-inch stroke, two piston-valves are used, both in one divided steam-chest at the side of the cylinder: the upper valve, double-ported, controlled by the governor, producing admission and cut-off; the lower, single-ported, moved by an ordinary eccentric, controlling release and compression.

Only moderate speeds are calculated on, — 75 revolutions per minute for 48-inch stroke, and 125 revolutions for 24-inch stroke, corresponding to 600 feet per minute piston-speed in the former case, and 500 feet in the latter. No scientific tests of these engines have been made; but diagrams taken from them are excellent, and they bear a good reputation.

*William A. Harris*, Providence, R.I., has long manufactured a class of steam-engines, which, under the name of Harris-Corliss engines, frankly recognize their indebtedness to Mr. George H. Corliss, but with sufficient modification of detail to justify the qualifying prefix of Mr. Harris's name.

A particular description of the modifications introduced by Mr. Harris, such as his self-packing valve-stems, his peculiar form of releasing tappets, and his rather larger pins and connections in the valve-gear, hardly falls within the scope of this paper, and will be found in Tolhausen's Uhland. These engines are largely used. Indeed, Mr. Harris enjoys the honorable distinction of having been one of the very few who recognized the merits of the Corliss engine and the rights of Mr. Corliss, and took a license from him to build his engine before the expiration of his patents. An account of a competitive test of one of these engines is given below.

*The Reynolds-Corliss Engine*, built by E. P. Allis & Co., Milwaukee, is in nearly all essential respects a Corliss engine, — with certain modifications of detail, more or less important, — which has obtained a wide reputation, and made an excellent record. It is described in Tolhausen's Uhland, and its peculiarities cannot be dwelt on here. An account of a trial of one of these engines, in competition with one of each of the preceding and following engines, will be found below.

*Jerome Wheelock*, Worcester, Mass., makes an engine which is, in all its most important features, a Corliss engine, yet more extensively modified. The valves, no longer cylindrical segments, as in the Corliss, the Harris-Corliss, and Reynolds-Corliss engines, are segments of conic frustums, provided with steel collars, serving as "steps," to adjust them endwise in their seats.

All four of the valves are placed below the cylinder, which is horizontal, the cut-off valves being placed directly back of the steam-distributing valve, so that the cylinder has but two ports, corresponding in position to the exhaust-ports of the Corliss engine. Exhaust takes place through a "cup" in the steam-distribution valve.

This engine is also described in Tolhausen's Uhland. Three engines of the three last preceding styles — Harris-Corliss, Reynolds-Corliss, and Wheelock — were elaborately tested by Mr. John W. Hill at the Millers' International Exhibition, Cincinnati, O., in June, 1880.

A table of the leading dimensions of these three engines is subjoined.

| | |
|---|---|
| Consumed when not pumping | 273,041 |
| Consumed in pumping | 660,865 |
| Total coal consumed | 933,906 |
| Total number of gallons pumped in 12 months | 441,061,225 |
| Mean head in feet against the pump, no allowance for frictions in suction | 264.19 |
| Mean duty in pounds of water raised 1 foot per 100 pounds of coal used for all purposes, no deduction for ashes and residue, | 106,203,760 |
| Mean duty in pounds of water raised 1 foot per 100 pounds of coal used for all purposes except warming, no deduction for ashes and residue | 108,402,320 |

### HORIZONTAL COMPOUND ENGINE.

In the Nourse Mill of the Social Manufacturing Company, Woonsocket, R.I.

This engine, designed by Mr. George H. Corliss, and built by the Corliss Steam Engine Company under a guaranty to run a year with a consumption of no more than 1.75 pounds of coal per horse-power and per hour, — all the coal fired during the year for supplying this engine with steam being divided by the mean indicated horse-power and by the number of hours' run of the engine, — is a fine example of its class.

It is a tandem, receiver, double engine, combining the effort of the two pair of pistons upon a single fly-wheel shaft with cranks set "quartering." The cylinder diameters are respectively 20 and 36 inches. The length of stroke common to both is 6 feet, and there is a space of about 4 feet between the end-casings of the two cylinders, to give access to the low-pressure piston.

The connecting-rod is 18 feet in length, so that the entire engine, from the centre of crank-shaft to the outer end of the high-pressure cylinder, occupies a length of about 42 feet. The fly-wheel is 30 feet in diameter, and has a rim 110 inches wide with four belt-faces. The weight of the fly-wheel, crank-shaft, cranks, and eccentrics, is about 54.5 tons, say 120,000 pounds.

The normal speed is 57 revolutions per minute; so that the velocity of the pistons is 684 feet per minute, and that of the belt 92 feet more than a mile per minute.

The weight of the reciprocating parts is 7,711 pounds, and at normal speed their momentum is equal to 19.38 pounds pressure per square inch on the area of both pistons.

The normal boiler-pressure is 110 pounds per square inch above the atmosphere; and about 8 pounds pressure above atmosphere is carried in the receiver.

exists in the case of engines pumping into a reservoir against an hydraulic head nearly constant. The quantity of feed-water supplied to the boilers, per indicated horse-power, per hour, was, for the entire engine, 17.5 pounds, to which must be added the quantity condensed in the jackets, about 10 per cent, making the total 19.25 pounds, which agrees very well with the coal consumption.

Referred to the work done in the high-pressure cylinders alone, the feed-water was 30 pounds per indicated horse-power, per hour, besides jacket-condensation.

### CORLISS ENGINE AT THE PETTACONSET PUMPING-STATION, PROVIDENCE, R.I.

In this case, Mr. Corliss erected upon ground, "as nature made it," a complete pumping-station, — engines, boilers, and pumps, with suitable brick buildings, including their foundations, pump-well and conduit, and every instrument and appliance ready for continuous use, with guaranty of 9,000,000 gallons capacity in 24 hours, and 100,000,000 foot-pounds duty for each 100 pounds of coal; all for a round and moderate sum.

The site presented difficulties, in an extensive bed of quicksand; difficulties overcome by ramming cobble-stones and shingle into the quicksand until the latter lost its mobility, and the commingled mass became as solid as hard-pan, — an expedient coming within the domain of the civil engineer.

The engine is a vertical, double-beam, receiver engine, with a single air-pump, jet-condenser, crank-shaft, and fly-wheel, and four single-acting plunger-pumps.

The cylinders are respectively 18 and 36 inches in diameter, and have a stroke of 6 feet. The pump-plungers are 19 inches in diameter, with 3 feet stroke; and each pump-chamber has 92 valves for inlet, and the same number for delivery, each set having an aggregate area much larger than the area of a cross-section of the plunger.

Weir measurements made near the pumping-station, and repeated at the reservoir 5,000 feet distant, revealed a loss of action, or "slip," of the pumps, of a very little less than 1 per cent of their computed capacity.

The speed is adjustable by hand; and when set at any number of revolutions per minute, between 20 and 50, the normal speed is maintained by the automatic action of the governor.

At a speed of 36 revolutions per minute, the quantity of water actually delivered into the reservoir, in 24 hours, is 9,066,483 Winchester gallons; at 50 revolutions, 12,579,618 gallons.

. The valves and valve-gear are of Mr. Corliss's well-known type, and of construction similar to that shown in the "Centennial" engine. Steam is carried at the normal pressure of 125 pounds above atmosphere, and is admitted at full pressure to the jacket of the high-pressure cylinder, which covers both ends and sides, whence steam is admitted by the valves to the cylinder, and water is drained off and returned to the boilers.

The jacket of the low-pressure cylinder — ends and sides — forms part of the receiver; and water from the receiver is drained off, pumped through a tubular heater in the boiler flues, and returned to the receiver as superheated steam. Feed-water is taken from the hot-well, and pumped first through a heater in the passage from the low-pressure cylinder to the condenser, which raises its temperature about 30° Fah., and then to a second heater in the flue, directly beneath the re-heater for drainage from the receiver, where it is heated up to about the temperature of the water in the boiler. The pressure in the receiver is about 8.5 pounds per square inch above atmosphere, and, in the condenser, about 12.5 pounds below.

The plant comprises 4 upright boilers, 64 inches in diameter and 14 feet long, with 84 flues each, 3 inches in external diameter; but only 3 are used, even when the engine is running at 50 revolutions per minute.

The aggregate fire-grate area in use is 94.5 square feet; and the rate of combustion is 5.5 pounds per hour, on each square foot of fire-grate area, at the usual speed of 36 revolutions per minute, and 7.62 pounds at the maximum speed of 50 revolutions.

A trial of this engine, on behalf of the city of Providence, was made during the week beginning Monday morning, May 22, 1882, and ending Saturday evening, May 27, 1882, by Mr. Samuel M. Gray, city engineer, with adequate assistance. Fires were started under the three boilers, which had cooled down from the Saturday before, at 6.50 A.M. on Monday; and 450 pounds of wood were used for kindling, called equal to 180 pounds of coal.

The pumps ran from 12 h. 8 m. to 12 h. 40 m. each day, 74 h. 45 m. during the 6 days, and, on an average, 12 h. 27 m. 30 s. each day. The fires were banked every night except Saturday, when they were suffered to run down as on the previous Saturday.

The total quantity of coal (Cumberland, bituminous) thrown on the grates during the week was 36,336 pounds; and, adding the coal equivalent of the kindling-wood (180 pounds) the fuel consumed was equal to 36,516 pounds of coal. No deduction was made for ashes and clinkers, which was equal to 9.1 per cent of the fuel.

During the trial, the engine pumped 28,360,162 gallons of water, at the rate of 9,105,604 gallons in 24 hours, against a mean total head — including suction, but without allowance for friction or resistance in suction-pipe and pump — of 174.99 feet; and, the weight of the gallon being taken at 8.3345 pounds, the duty in foot-pounds, for each 100 pounds of coal, was 113,271,000.

Computed on the coal used in running, exclusive of kindling and banking fires, the duty per 100 pounds of coal was 138,035,000 foot-pounds.

The report for the year 1883 is as follows: —

| | |
|---|---|
| Total number of hours run | 3,952.09 |
| Number of days on which the engine ran | 200 |
| Mean number of hours run per day | 13.63 |
| Gallons pumped, total | 1,489,735,931 |
| Gallons pumped, daily mean | 5,137,020 |
| Gallons pumped, hourly mean | 376,949 |
| Coal consumed, pounds | 2,063,539 |
| Coal equivalent of wood used, ⅓ of 40,789 pounds | 13,600 |
| Total coal equivalent of fuel used for all purposes | 2,077,139 |
| Ratio of ashes and clinkers to the total fuel, per cent | 15.5 |
| Total number of revolutions | 8,518,131 |
| Mean head of water, feet | 177.45 |
| Number of cubic feet of water delivered into reservoir, per revolution | 23.38 |
| Mean weight of 1 cubic foot, pounds | 62.331 |
| Duty, $= \frac{8{,}518{,}131 \times 177.45 \times 23.38 \times 62.331 \times 100}{2{,}077{,}139} =$ | 106,048,000 |

If the proportion of ashes and clinkers had been no more during the year than during the trial of a week, the duty would have been greater in the proportion of 0.909 to 0.845, and would have exceeded 114,000,000.

### STEAM-ENGINES OF MEDIUM SIZE AND MODERATELY HIGH SPEED.

We come now to the consideration of a group of engines, for the most part manufactured in advance of orders, and bought for various purposes, according to the judgment of the purchaser, with or without expert advice.

Among the manufacturers of steam-engines thus loosely grouped together, it is eminently proper to name Mr. George H. Corliss first; for although others, not a few, now rival him in certain special qualities, some do this by avowed appropriation of his inventions, no longer protected by patents; while all, no less in the United States than elsewhere throughout the world, are indebted to principles of

which he was among the first to discover the transcendent importance, and to mechanical combinations, or their equivalents, which he was the first to invent.

It must be unnecessary to attempt, in this place, any description of the characteristic features of the Corliss engine. *Il a fait le tour du monde.* His releasing valve-gear has been criticised by Professor Releaux and by others, as mechanically imperfect; but these criticisms seem not to be well-founded.

No one, it is presumed, objects to intermittent motion in the escapement of a watch, or in the lock of a gun, nor yet in the tripping mechanism of a pile-driver. The advantages of this motion in closing a steam-valve at cut-off are so weighty, and the inconveniences of it, if indeed real, are so slight, that it may well be considered practically perfect up to 70 or 80 revolutions per minute. For speeds much above these, it seems to be ill-adapted.

The wrist-plate, giving a rapid motion to the valves in opening and in closing, and a period of comparative rest at the extremities of its throw, attains, by means mechanically unobjectionable, all that has been sought in vain from impracticable cams.

The valve itself, a cylindrical slide, has established its durability and its tightness by the experience of a generation of men.

Mr. Corliss, as the head and front of the Corliss Steam-engine Company, stands toward the public in a twofold relation: first, as an engineer, prepared to design and construct steam-engines for special service; and, second, as a manufacturer of steam-engines for sale, to be used for various purposes, without special adaptation to any. In the first relation, he nicely adapts all the parts of his mechanism to the attainment of the end in view; and such engines as we have considered are examples of the result.

In the latter relation, the result will depend on the judgment and skill of the purchaser when he is his own engineer, and on the skill of his engineer when he employs one. Engines too large or too small for their load, supplied with water-clogged steam from ill-arranged or inadequate boilers, or run at unsuitable speeds, or with leaky pistons and mal-adjusted valves, will give no satisfactory results, although manufactured by Mr. Corliss.

These remarks are general, and are applicable to all competent steam-engine manufacturers, with a degree of force proportioned to the real excellence of their respective engines under most favorable conditions.

A Corliss engine at the Lancaster Mills, Clinton, Worcester County, Mass., was tested in February, 1884, under the direct super-

vision of Mr. George W. Weeks, agent of the mills, a member of the American Society of Mechanical Engineers, well known to the writer, who vouches for his candor and intelligence.

This is what is usually called a "double engine," that is, a pair of engines, right and left hand, with a fly-wheel and shaft in common, and cranks set at right angles. The dimensions are: diameter of cylinders, 26 inches; length of stroke, 5 feet; fly-wheel, 30 feet in diameter, 6 feet belt-face; air-pump, 34 inches in diameter, 12 inches stroke.

The cylinders are not steam-jacketed. Steam is supplied by five return-tubular, externally fired horizontal boilers, 60 inches in diameter outside of the smaller courses, with 76 flues, 3.25 inches outside diameter, and 19 feet 8 inches long; set with overhanging smoke-box, the front flue-sheets being about in the plane of the arch-fronts.

| | |
|---|---|
| Heating-surface . . . . . | .1345 × 5 = 6725 square feet |
| Fire-grate area . . . . . | 28.5 × 5 = 142.5 square feet |
| Ratio of heating-surface to fire-grate area . . . . . | 47 to 1 |
| Steam-pressure in boiler, in pounds per square inch above atmosphere, | 87. |
| Vacuum, in pounds per square inch below atmosphere . . . . . | 13.02 |
| Mean speed of engine in revolutions per minute . . . . . | 52.71 |
| Mean piston-speed, feet per minute . . . . . | 527.1 |
| Clearance, in terms of volume swept through by the piston . . . . | .0239 |

The test was continued four days, and sets of diagrams were taken six times each day, three times in the forenoon and three in the afternoon. The first set was taken soon after starting the engine, at 6.50 to 6.58 A.M.

The second set was taken between 8.06 and 9.34 A.M.; the third, between 9.48 and 11.12; the fourth, between 2.02 and 3.06 P.M.; the fifth, between 2.48 and 3.44; and the sixth, between 4.03 and 4.48.

The least power observed was 641.90 horse-power, the greatest 703.35, a range of only about 9 per cent. The means for the respective days were: —

*Horse-power.*

| | |
|---|---|
| First day . . . . . | 684.13 |
| Second day . . . . . | 666.92 |
| Third day . . . . . | 663.51 |
| Fourth day . . . . . | 669.09 |
| Mean of all . . . . . | 670.91 |

There were burned under the boilers from 6 o'clock of the evening preceding the first day of the test, to 6 o'clock P.M. of the last day, when the test ended, 57,000 pounds of coal, which yielded 4,600

pounds of dry ashes and refuse, leaving 52,400 pounds of combustible.

Ratio of ash to coal, 8.07 per cent. The hours run were 11 hours each day, 44 in all.

| | |
|---|---|
| Coal per hour, pounds | 1,295.45 |
| Coal per hour, and per indicated horse-power, pounds | 1.93 |
| Combustible per hour, pounds | 1,190.91 |
| Combustible per hour, and per indicated horse-power, pounds | 1.77 |

A test of the evaporative efficiency of the boilers and coal, not simultaneous with the engine-test, but some time before, gave an actual evaporation of 10.58 pounds of water per pound of coal burned; or, corrected, by estimate, for water blown off during the day, and water pumped in at night, 10.07 pounds.

Computed from the indicator-cards, the quantity of water "visible" as steam was equal to 8.67 pounds for each pound of coal burned during the test, which would indicate the presence of 13.9 per cent of the feed-water in the liquid form in the cylinder.

The number of diagrams taken may be thought too few to give assurance of the true mean of the power during the 44-hours' run; but if the smallest mean be taken, that for the third day (663.51 indicated horse-power), the coal consumption per hour and per indicated horse-power becomes 1.95 pounds, against 1.89 pounds if the largest mean-power, that for the first day (684.13 indicated horse-power), be taken.

Again, if we take the smallest power observed during the four days, at 4.03 to 4.05 P.M. of the second day, 641.90 indicated horse-power, and compare the result with that obtained by using the largest observed power, at 9.31 to 9.34 A.M. of the first day, 703.35, we have respectively 2.02 and 1.84 pounds per indicated horse-power per hour, each differing from the mean, 1.93, only 4.5 per cent.

Upon the basis of 10 pounds of water evaporated under actual conditions, for each pound of coal burned, we have 19.3 pounds of water per indicated horse-power and per hour; and by the indicators 16.73 pounds; so that, of the feed-water supplied to the boilers 86.7 per cent was accounted for by the indicators, and 13.3 per cent was present as liquid water. (Published in "Cotton, Wool, Boston, Mass., Feb. 9–16, 1884.)

For the year ending April 26, 1884, the coal burned in the [illegible] boilers, supplying steam for all purposes, including [illegible] running-time of this engine, at 670 indicated horse-[illegible] from numerous indicator diagrams, amounted to

1,967 tons, equal to 4,406,080 pounds, which gives 2.14 pounds of coal consumed in the mill, for all purposes, for each indicated horse-power exerted one hour.

It may be thought that too much space has been given to this test; but it is so good an example of valuable work within the reach of nearly all users of steam-engines, that it has been thought well to bring it to notice in this manner.

*The Putnam Machine Company*, Fitchburg, Mass., were among the earlier manufacturers of an excellent class of automatic cut-off, horizontal engines, of medium speed and moderate power.

Being well described in Tolhausen's Uhland, it will be unnecessary to describe them here. By the use of double-seated poppet-valves and an ingenious combination of cams and levers, the cut-off is controlled by the governor, and an excellent distribution of steam is effected, with satisfactory uniformity of speed.

The writer has occasionally tested an engine of this construction, 12-inch cylinder, 30-inch stroke, during a period of 17 years, and always found it tight, and in perfect order, almost without repairs.

This valve-gear is not well adapted to speeds higher than 90 or 100 revolutions per minute.

*Charles H. Brown & Co.*, also of Fitchburg, by means of gridiron slide valves, actuated by cams and levers, and detaching mechanism controlled by the governor, obtain very prompt and full admission, almost instantaneous cut-off, and free release, and produce indicator diagrams almost ideally perfect.

In point of mechanical execution and finish, the Brown engines are singularly beautiful, and in all the higher qualities of design and proportion they are excellent. This engine, also, is described in Tolhausen's Uhland.

*The Fitchburg Steam-engine Company*, also of Fitchburg, Mass., a newer enterprise, is now making an automatic cut-off engine of much higher order than the small vertical engines described in Tolhausen's Uhland.

They make a peculiar form of centrifugal governor placed on the crank-shaft; a kind of governor which has gained great favor within the last ten years, and assumed a multitude of forms. We shall again have occasion to speak of this governor.

In the form under notice, which is excellent, the eccentric is guided in its transverse motion across the shaft, by means of a sort

of parallel motion, consisting of two levers connected with ears on opposite sides of the eccentric-block, describing equal arcs in opposite directions; thus avoiding the guides used in some other forms, while preserving constant lead of valve. Weights attached to these levers exactly counterbalance the weight of the eccentric and its strap, and, in vertical engines, the weight of the valve-rod and connections also, in all positions, leaving the eccentric neutral under all the impulses of the governing mechanism. This consists of weights on arms pivoted to opposite sides of an incasing pulley, connected by rods to the balancing-arms already mentioned, acting centrifugally with a force proportioned to the rapidity of revolution, opposed by springs which act centripetally with a force proportioned to the compression produced by the revolving-weights.

These forces being properly adjusted, so as to be in equilibrium at normal speed, this speed will be maintained so long as the load and the mean effective pressure of steam in the cylinder remain relatively unaltered.

Any increase of load, with steam-pressure constant, will cause a corresponding diminution of velocity, and therefore of centrifugal force in the weights, and give a preponderance to the springs acting centripetally, so as to turn the eccentric to delay the cut-off, and so to increase the mean effective pressure. On the other hand, any diminution of load will give preponderance to the centrifugal force of the weights, and turn the eccentric so as to hasten the cut-off, and reduce the mean effective pressure.

When a single piston-valve is used, release and exhaust-closure are affected in the same sense as cut-off: with early cut-off, there is early release and early closure of the exhaust; and with later cut-off, both release and closure are retarded, as in a link-motion.

The single valve is used only in the smaller engines, especially in vertical engines. In larger, horizontal engines, from 9-inch diameter and 24-inch stroke to 24-inch diameter and 48-inch stroke, two piston-valves are used, both in one divided steam-chest at the side of the cylinder: the upper valve, double-ported, controlled by the governor, producing admission and cut-off; the lower, single-ported, moved by an ordinary eccentric, controlling release and compression.

Only moderate speeds are calculated on, — 75 revolutions per minute for 48-inch stroke, and 125 revolutions for 24-inch stroke, corresponding to 600 feet per minute piston-speed in the former case, and 500 feet in the latter. No scientific tests of these engines have been made; but diagrams taken from them are excellent, and they bear a good reputation.

*William A. Harris*, Providence, R.I., has long manufactured a class of steam-engines, which, under the name of Harris-Corliss engines, frankly recognize their indebtedness to Mr. George H. Corliss, but with sufficient modification of detail to justify the qualifying prefix of Mr. Harris's name.

A particular description of the modifications introduced by Mr. Harris, such as his self-packing valve-stems, his peculiar form of releasing tappets, and his rather larger pins and connections in the valve-gear, hardly falls within the scope of this paper, and will be found in Tolhausen's Uhland. These engines are largely used. Indeed, Mr. Harris enjoys the honorable distinction of having been one of the very few who recognized the merits of the Corliss engine and the rights of Mr. Corliss, and took a license from him to build his engine before the expiration of his patents. An account of a competitive test of one of these engines is given below.

*The Reynolds-Corliss Engine*, built by E. P. Allis & Co., Milwaukee, is in nearly all essential respects a Corliss engine, — with certain modifications of detail, more or less important, — which has obtained a wide reputation, and made an excellent record. It is described in Tolhausen's Uhland, and its peculiarities cannot be dwelt on here. An account of a trial of one of these engines, in competition with one of each of the preceding and following engines, will be found below.

*Jerome Wheelock*, Worcester, Mass., makes an engine which is, in all its most important features, a Corliss engine, yet more extensively modified. The valves, no longer cylindrical segments, as in the Corliss, the Harris-Corliss, and Reynolds-Corliss engines, are segments of conic frustums, provided with steel collars, serving as "steps," to adjust them endwise in their seats.

All four of the valves are placed below the cylinder, which is horizontal, the cut-off valves being placed directly back of the steam-distributing valve, so that the cylinder has but two ports, corresponding in position to the exhaust-ports of the Corliss engine. Exhaust takes place through a "cup" in the steam-distribution valve.

This engine is also described in Tolhausen's Uhland. Three engines of the three last preceding styles — Harris-Corliss, Reynolds-Corliss, and Wheelock — were elaborately tested by Mr. John W. Hill at the Millers' International Exhibition, Cincinnati, O., in June, 1880.

A table of the leading dimensions of these three engines is subjoined.

## TABLE OF DIMENSIONS.

| | Units. | Harris-Corliss. | Reynolds-Corliss. | Wheelock. |
|---|---|---|---|---|
| Diameter of cylinder . . . . | inches, | 18.03 | 18.02 | 18.26 |
| Diameter of piston-rod . . . | inches, | 2.68 | 2.81 | 2.94 |
| Diameter of steam-pipe . . . | inches, | 6 | 5 | 7 |
| Diameter of exhaust-pipe . . | inches, | 8 | 7 | 8 |
| Diameter of fly-wheel . . . | feet, | 16 | 16 | 16 |
| Diameter of air-pump cylinder, | inches, | 9.81 | 17 | |
| Diameter of injection-pipe . . | inches, | 2 | 2 | 2 |
| Diameter of overflow-pipe . . | inches, | 6 | 7 | 3.5 |
| Stroke of piston . . . . . | inches, | 48 | 48 | 48 |
| Stroke of air-pump . . . . | inches, | 12 | 12 | |
| Area of steam-piston . . . . | sq. inches, | 255.3172 | 255.0354 | 261.8726 |
| Area of cross-sec. of piston-rod, | sq. inches, | 5.641 | 6.2125 | 6.7771 |
| Area of each steam-port . . | sq. inches, | 13.5 | 15.75 | 30 |
| Area of each exhaust-port . . | sq. inches, | 24.75 | 27 | 30 |
| Width of fly-wheel face . . . | inches, | 25 | 25 | 25 |
| Weight of fly-wheel . . . . | pounds, | 11,950 | 14,694 | 12,000 |
| Total weight of engine . . . | pounds, | 29,950 | 36,874 | 21,000 |
| Clearance in terms of stroke . | | .0193 | .0265 | .0142<br>.0235 |

## CONDENSED SUMMARY OF RESULTS.

### CONDENSING.

| | Units. | Harris-Corliss. | Reynolds-Corliss. | Wheelock. |
|---|---|---|---|---|
| Duration of trial . . . . . | hours, | 10 | 10 | 10 |
| Boiler-pressure, mean . . . | lbs. per sq. in. | 96.09 | 95.83 | 96.25 |
| Atmosphere by barometer . . | " | 14.52 | 14.60 | 14.45 |
| Vacuum, mean . . . . . | " | 12.61 | 12.50 | 11.78 |
| Revolutions per minute . . . | " | 75.83 | 75.383 | 74.472 |
| Initial pressure . . . . . | " | 90.072 | 91.09 | 88.086 |
| Cut-off in terms of stroke . . | " | .11867 | .12406 | .13084 |
| Pressure at cut-off . . . . . | " | 86.966 | 86.329 | 77.697 |
| Terminal pressure, absolute . | " | 14.568 | 15.161 | 14.044 |
| Mean effective pressure . . . | " | 35.6722 | 35.4036 | 33.9396 |
| Ratio of expansion . . . . | | 6.95 | 6.67 | 6.35 |
| Theoretical cut-off . . . . . | | .14386 | .14093 | .15753 |
| Indicated horse-power . . . | i. h. p., | 165.578 | 162.995 | 158.385 |
| Friction of engine, light . . | " | 9.573 | 10.262 | 7.814 |
| Other frictions, and air-pump . | | 10.928 | 9.538 | 6.224 |
| Net effective power . . . . | i. h. p., | 145.077 | 143.195 | 143.946 |

CONDENSED SUMMARY OF RESULTS — CONDENSING (*Concluded*).

| | Units. | Harris-Corliss. | Reynolds-Corliss. | Wheelock. |
|---|---|---|---|---|
| Water per indicated horse-power per hour | pounds, | 19.364 | 19.489 | 19.265 |
| Coal per indicated horse-power per hour | pounds, | 1.936 | 1.949 | 1.927 |
| Relative economy | | .98848 | .99487 | 1.00000 |
| Steam, by diagrams | per cent, | 71.034 | 72.199 | 71.449 |
| Condensing water per pound of feed-water | pound, | 32.53 | 30.88 | 24.74 |

The air-pump of the Harris-Corliss engine was driven by the engine; that of the Reynolds-Corliss, by a separate engine or steam-pump. The Wheelock engine had a Buckley siphon condenser, requiring only sufficient power to lift the water to supply it.

NON-CONDENSING.

| | Units. | Harris-Corliss. | Reynolds-Corliss. | Wheelock. |
|---|---|---|---|---|
| Duration of trial | hours, | 10 | 10 | 10 |
| Boiler-pressure | lbs. per sq. in. | 96.32 | 96.61 | 96.32 |
| Atmosphere by barometer | " | 14.515 | 14.613 | 14.481 |
| Revolutions per minute | hours, | 75.81 | 75.33 | 76.072 |
| Initial pressure | lbs. per sq. in. | 89.522 | 89.994 | 88.499 |
| Cut-off in terms of stroke | | .13627 | .15956 | .16966 |
| Pressure at cut-off | lbs. per sq. in. | 85.91 | 84.757 | 76.875 |
| Terminal pressure, absolute | " | 17.037 | 17.413 | 17.460 |
| Mean effective pressure | " | 28.9397 | 29.7508 | 29.3632 |
| Ratio of expansion | | 6.35 | 5.42 | 5.14 |
| Theoretical cut-off | | .15748 | .18461 | .19448 |
| Indicated horse-power | I. H. P., | 134.293 | 137.017 | 139.973 |
| Friction of engine, light | " | 9.561 | 10.255 | 7.982 |
| Other frictions, and air-pump of Harris-Corliss engine | " | 4.989 | 5.070 | 5.280 |
| Net effective power | " | 119.743 | 121.692 | 126.711 |
| Water per indicated horse-power per hour | pounds, | 22.054 | 23.933 | 24.926 |
| Coal per indicated horse-power per hour | pounds, | 2.205 | 2.393 | 2.493 |
| Relative economy | | 1.0000 | .92146 | .88476 |
| Steam, by diagrams | per cent, | 75.346 | 72.832 | 75.726 |

It surely is not uninteresting to observe that engines designed and built by three independent manufacturers, not in concert, but in rivalry, with variations of detail by no means inconsiderable, should have arrived at results so nearly identical that the differences hardly exceed the limits of probable error, even in this exceptionally skilful test, every line of which is so instructive that it has been difficult to condense it. So evenly matched were they, that the eminent and candid expert who conducted the tests professed himself unable to award the precedence to any one of them; and, although an award was finally made, the reasons for it were too slight to escape criticism.

It is further noticeable, that, in the trials with condensation, the results are substantially identical with those obtained by Mr. Weeks with the double Corliss engine, 26 inches diameter of cylinder, 60-inch stroke, except, indeed, that in the latter case all the coal for kindling and banking fires was included. The gain by condensation appears to be: Harris-Corliss, 12 per cent; Reynolds-Corliss, 19 per cent; Wheelock, 23 per cent; and the Corliss engine at Lancaster Mills, 19 per cent. The mean for these four engines is 18 per cent.

*The Buckeye Steam-engine Company*, Salem, Columbiana County, Ohio, have long manufactured an automatic cut-off engine, widely and favorably known for good qualities of design, construction, and operation. It is very well described in Tolhausen's "Uhland," and in the report of the judges of Group XX. at the International Exhibition in Philadelphia in 1876.

Engines altogether similar in design, with some formal differences, have for several years been manufactured by the *Hartford Engineering Company*, Hartford, Conn., one of which was recently tested by the writer in conjunction with Mr. George H. Barrus, at the mill of the Crompton Company, Kent County, R.I.

This was a double engine, having cylinders 17 inches in diameter, and a stroke of 24 inches, with a fly-wheel and shaft in common, and cranks set at right angles. A Bulkley siphon condenser is arranged to use with it at will. Steam is supplied by three Corliss boilers, which also supply the mill with steam for all purposes; but, during the tests, two only were used for the engine, the third being detached for the other uses of the mill.

These boilers are of the Corliss "rolling-pin" type, having a vertical cylindrical shell 90 inches in diameter and 10 feet long, with a "water-leg" in the centre 31 inches in diameter and 4 feet 8 inches

long, standing on the floor of the boiler-house; and a steam-dome 31 inches in diameter and 6 feet long rising from the centre of the cylindrical shell. In the annular space around the water-leg and steam-dome, there are 248 flues, 2 inches in outside diameter and 10 feet long, through which the gaseous products of combustion pass up to and around the steam-dome, and thence off to the chimney.

The lower end of the water-gauge glass is 5 feet 4 inches above the lower tube-sheet, and its upper end is 3 feet 9 inches below the upper tube-sheet; which accounts for the superheating observed in the steam at the engine, 120 feet distant.

The heating-surface in the two boilers is 2,804 square feet, and the fire-grate area 90 square feet; so that the ratio of the former to the latter is 31.16 to 1, counting together the water and steam-heating surface. The ratio of water-heating surface alone to fire-grate area is 19.9 to 1. Steam was much superheated, and the escaping gases went off very hot, as was shown by the melting of a glass thermometer-tube in the flue.

Neither the makers of the boilers nor of the engine were responsible for the boiler-setting, as the boilers were bought at second hand, and set up by the mill-owners. The boiler performance is subjoined: —

PERFORMANCE OF THE BOILERS.

| | | March 27. Condensing. | March 28. Non-condensing. |
|---|---|---|---|
| Temperature of feed-water | degrees F. | 51.8 | 49.1 |
| Barometric pressure | lbs. per sq. in. | 14.45 | 14.506 |
| Boiler pressure above atmospheric | lbs. per sq. in. | 79.5 | 77.8 |
| Superheating | degrees F. | 65. | 88.9 |
| Evaporation per pound of coal | pounds. | 6.333 | 6.126 |
| Evaporation per pound of combustible | pounds. | 7.63 | 7.387 |
| Equivalent evaporation from, and at 212 degrees F., per pound of coal | pounds. | 7.609 | 7.375 |
| Do. per pound of combustible | pounds. | 9.167 | 8.893 |
| Coal burned per hour per square foot of fire-grate area | pounds. | 12.1 | 14.2 |
| Ratio of ashes and refuse to coal burned | | .170 | .171 |
| Ratio of boiler performance to normal duty taken at 10,000 B. t. u. per pound of coal with one-sixth refuse | | .868 | .837 |

DIMENSIONS RELATING TO ENGINE.

| | | Right-hand cylinder. | Left-hand cylinder. |
|---|---|---|---|
| Diameter of cylinder | inches. | 17.07 | 17.03 |
| Diameter of piston-rod | inches. | 2.75 | 2.75 |
| Length of stroke | inches. | 24.25 | 24.14 |
| Clearance in terms of stroke, front | | .0218 | .0278 |
| Clearance in terms of stroke, back | | .0191 | .0207 |
| Main steam-pipe, diameter | inches. | 10 | 10 |
| Branch pipes, diameter | inches. | 6 | 6 |
| Diameter of fly-wheel | feet. | 10 | 10 |
| Width of belt-face | inches. | 40 | 40 |

PERFORMANCE OF THE ENGINE.

| | | March 27. Condensing. | March 28. Non-condensing. |
|---|---|---|---|
| Duration of trial | | 10h. 22m. | 10h. 7.5m. |
| Mean indicated horse-power | i. h. p. | 327.27 | 300.6 |
| Feed-water per indicated horse-power per hour | pounds. | 20.917 | 26.1 |
| Superheating near engine | degrees F. | 11. | 35. |
| Feed-water per indicated horse-power per hour, corrected for superheating | pounds. | 21.015 | 26.538 |
| Mean pressure in steam-pipe | lbs. per □″. | 78. | 76.3 |
| Mean vacuum near engine | lbs. per □″. | 11.49 | |
| Mean effective pressure | lbs. per □″. | 38.5 | 35.50 |
| Mean speed, revolutions per minute | | 154. | 153.1 |
| Mean piston speed, feet per minute | | 621. | 617.4 |
| Coal per indicated horse-power per hour | pounds. | 3.3 | 4.25 |
| Gain by condensing | ratio. | .25 | |

Two Thompson and two Tabor indicators were used, and interchanged occasionally; and all the springs and pressure-gauges were tested at the close of the trial. The exponent of the expansion curve in the expression, $P_2 = \frac{P_1 V_1^n}{V_2^n}$; or, $PV^n = C$, a constant, was found, by the logarithmic method, to be $n = 1.118 =$ about $\frac{10}{9}$.

The engines were examined for tightness at the beginning and end of each run. All clearance spaces were accurately ascertained. Diagrams were taken simultaneously every 10 minutes, and, during the first 10 minutes of each run, once a minute.

PERFORMANCE OF THE ENGINE, DEDUCED FROM A SELECTED SET OF INDICATOR DIAGRAMS TAKEN IN THE AFTERNOON OF EACH DAY, ABOUT EQUAL TO THE MEAN FOR EACH DAY, CORRECTED FOR ERRORS OF INDICATOR-SPRINGS AND ALL SOURCES OF INACCURACY.

| | 1884. March 27, P.M. Condensing. | | 1884. March 28, P.M. Non-condensing. | |
|---|---|---|---|---|
| | Right-hand. | Left-hand. | Right-hand. | Left-hand. |
| Barometric pressure | 14.45 | 14.45 | 14.51 | 14.51 |
| Initial pressure above atmosphere | 75.23 | 73.77 | 76.20 | 76.67 |
| Initial pressure, absolute | 89.68 | 88.22 | 90.71 | 91.18 |
| Pressure at cut-off, absolute | 74.08 | 71.70 | 72.88 | 72.66 |
| Pressure at release, absolute | 19.91 | 19.52 | 25.11 | 25.26 |
| Compression at end of stroke, absolute | 5.02 | 6. | 16.96 | 17.53 |
| Back pressure, mid-stroke, absolute | 4.09 | 4.63 | 15.46 | 15.66 |
| Point of cut-off; stroke | .265 | .260 | .340 | .334 |
| Point of release; stroke | .939 | .929 | .941 | .933 |
| Point of compression, stroke | .927 | .938 | .905 | .922 |
| Mean effective pressure | 42.02 | 40.29 | 37.67 | 37.19 |
| Steam at cut-off, pounds per indicated horse-power per hour | 15.78 | 15.86 | 20.67 | 20.90 |
| Steam at release, pounds per indicated horse-power per hour | 15.42 | 15.64 | 20.20 | 20.65 |
| Mean, steam at cut-off | 15.82 | | 20.78 | |
| Mean, steam at release | 15.53 | | 20.37 | |
| Ratio of steam at cut-off to feed-water | .771 | | .811 | |
| Ratio of steam at release to feed-water | .757 | | .795 | |

The quantity of condensing-water was measured approximately, and its temperature, as well as that of the out-flow, kept; and by this method 87.2 per cent of the heat rejected by the engine was accounted for. Had the performance of the boilers equalled 10,000 B. t. u. usefully imparted to the water per pound of coal (a result easily attainable), the consumption of coal per indicated horse-power per hour would have been: —

Condensing, 3.3 × .868 . . . . . 2.86 pounds
Non-condensing, 4.25 × .837 . . . . . 3.56 pounds

The superheating, while favorable to the engines, reduced the apparent efficiency of the boilers.

### THE ATLAS-CORLISS ENGINE,

Manufactured by the Atlas Engine Works, Indianapolis, Ind., justly acknowledges its indebtedness to Mr. Corliss, while it presents some peculiar features of considerable interest.

The four valves, situated as in the Corliss engine, are cylindrical segments actuated by wrist-plates; and the steam-valves are tripped by mechanism controlled by the governor, much as in the Corliss engine.

These steam-valves are placed in steel bushings having two port-openings, which give a double length of opening at the beginning of admission, and also provide for repair without disturbing the cylinder itself. Two eccentrics are used, in place of the single eccentric of Mr. Corliss, set on the shaft, — the exhaust eccentric nearly in the same angular position as in the Corliss engine, but the steam-eccentric about 90 degrees behind it, so that the cut-off has a range all the way from 0 to .875 stroke.

These eccentrics are not placed on the engine crank-shaft, but on a special shaft near the cylinder driven by a pair of equal gears from the crank-shaft. The governor is driven by gears from this eccentric shaft, thus avoiding the use of a belt.

The eccentrics are small, and the connections are short and direct. The Porter governor is used.

Flat slides are used, instead of the V-slides of Mr. Corliss; and the cross-head pin is placed in the middle of the length of the wear-plates, the wear of which is taken up by adjustable wedges.

The main bearing and the girder frame are cast in one piece. The stroke ranges from 3 to 5 feet; the speed, from 60 to 80 revolutions; and the piston-speed, from 480 to 600 feet per minute. No tests of these engines have come to the knowledge of the writer.

### THE PORTER-ALLEN ENGINE,

Manufactured by the Southwark Foundry and Machine Company, Philadelphia, has been completely transformed since its precursor, the "Allen Engine," was exhibited in England, and for a while manufactured by Whitworth & Co.; and considerably improved in matters of detail since it was described in the supplementary volume of Tolhausen's Uhland, in 1882.

Among these improvements, are the adjustable "pressure-plates" back of the steam-valves, which greatly facilitate the keeping of these valves tight, and also serve as very efficient relief-valves for

water in the cylinder, whenever greater pressure exists in the cylinder than in the steam-chest.

The workmanship of these engines, and the facilities of all kinds provided for accurate fitting and systematic inspection of their parts, are, probably, not surpassed in any mechanical establishment. The system of inspection requires the exact determination of the finished dimensions of every part, and the disposal of the inspected parts according to their degree of conformity to standard dimensions within certain prescribed limits of error.

If within the limit, the piece is accepted: if beyond the limit, it is laid aside for more accurate fitting, if the nature of the defect admits of remedy; if otherwise, it is inexorably rejected.

This engine, by reason of its four-ported steam and exhaust valves, its unbroken valve-connections, and the compensation afforded by its peculiar link for the inequalities of piston-speed near the two extremities of the stroke, by the solidity and excellence of its frame, and by the skilful adaptation of the weight of reciprocating parts to the rotatory velocity, is peculiarly well adapted to high speed.

The normal speeds range from 350 revolutions per minute for 12-inch stroke, to 80 revolutions per minute for 5 feet 6 inch stroke, giving piston-speeds from 700 to 880 feet per minute. Three pairs of these engines, 11.25 inches diameter of cylinder, 16-inch stroke, condensing, 200 to 250 indicated horse-power, have been running several years at the mill of the Willimantic Linen Company, Willimantic, Conn., at 350 revolutions per minute, giving a piston-speed of 933 feet; and cards taken from one of them by the writer show excellent distribution of steam.

The Porter-Allen engine has been extensively used for driving dynamos for electric lighting, but perhaps its most signal triumphs have been won in rolling steel plates and rails.

At the Cambria Iron-works, Johnstown, Penn., a Porter-Allen engine, 40-inch diameter of cylinder and 48-inch stroke, several years ago replaced a throttling, slide-valve engine, running at 82 revolutions per minute with empty rolls, but falling to 65 or 60 at every pass, so that by the time a rail was finished its temperature was very sensibly reduced, and its plasticity greatly lessened.

The Porter-Allen engine, running at the unalterable speed of 90 revolutions per minute, finished a rail with 11 passes instead of 15, without sensible diminution of temperature, and fully doubled the production (2,400 tons per week against 1,200), with greatly reduced

breakage, and a smaller proportion of defective rails. Of course there were other incidental advantages.

The Cambria Iron-works have in use, it is said, 14 of these engines of various sizes. An engine of 40-inch cylinder, 48-inch stroke, coupled directly to a train of rolls at the Otis Steel-works, Cleveland, O., rolls plates 10 feet in width, and of less width 50 feet in length, reducing $\frac{3}{8}$ inch at a pass.

The Troy Steel-works, Troy, N.Y., have three of these engines, now several years in use, driving roll-trains; and there are many others. One of these engines, 12-inch cylinder, 24-inch stroke, supplying power to the Clinton Wire-cloth Mill, Clinton, Worcester County, Mass., now more than ten years in use under the observation of the writer, recently ran six months at about 50 horse-power, as computed from daily indicator-diagrams, with a mean hourly consumption of 3 pounds of coal per horse-power, — all the coal burned during the whole period being divided upon the number of hours run.

The coal was a good quality of anthracite, egg-size. The engine is non-condensing, and not steam-jacketed, and during cold weather works against 3 or 4 pounds back-pressure, as exhaust-steam is used for warming the mill.

### THE HOADLEY PORTABLE ENGINE.

An engine designed, patented, and for several years manufactured by the writer, and now made by Messrs. George T. McLaughlin & Co., Boston, Mass., should be mentioned as the pioneer in this country of the large class of steam-engines with automatic cut-off controlled by a centrifugal governor placed on the crank-shaft, of which we have already noticed several examples, and shall meet others.

The genesis of this device appears to be as follows: Richard Wilcox of Bristol took out letters-patent of Great Britain, No. 2,574, of 1802, June 21, for several improvements in steam-engines and boilers, among which was a centrifugal regulator attached to the arms of a fly-wheel, complete as an automatic variable cut-off in all respects, except that no provision was made for centripetal action, by springs or otherwise.

The description is imperfect; but the drawing is clear, and the idea of regulating the speed by causing the speed itself to proportion the period of steam-admission to the requirements of the load, is clearly expressed. The device shown — a conical cam shifted endwise on the crank-shaft by the governor — is substantially the same

as that adopted by Mr. Corliss in one of his early engines, erected at the Calendar Works in Providence, in 1849; and applied in a little different form, about the same time, to a pumping-engine at the United-States Dry Dock in Brooklyn, N.Y.

Isaac Dodds of Masbrough, and William Owen of Rotherham, took out letters-patent of Great Britain, No. 8,219, of 1839, March 16, for an eccentric of variable throw, adjustable by hand, by means of a pair of wedges sliding in grooves on opposite sides of the crank-shaft, with their outer sloping edges parallel, embraced by a slotted eccentric, so that, as the wedges were moved forwards and backwards, the centre of the eccentric was moved towards or from the centre of the shaft, reducing or increasing the throw without affecting the angular advance of the eccentric, but disarranging the lead of the valve.

This device could not be used as a reverse-motion; and, indeed, the same patent describes another device for reversing, applicable to locomotives.

Only three months later, June 21, 1839, Jacob D. Custer of Norristown, Penn., took out letters-patent of the United States, No. 1,179, for a complete and perfect automatic cut-off engine, claiming: "Attaching the governor-balls to the fly-wheel of the engine, and connecting them to the eccentric in the manner specified, by which means the eccentric is made to move backwards and forwards in relation to the dead points of the crank, and thus to cut off the steam longer or shorter."

This seems to have been the first attempt, 27 years after Wilcox, to carry out his original invention; and it was 25 years later before another attempt was made (an abortive attempt), and 29 years before it was reduced to practice.

S. Lloyd Wiegand, of Philadelphia, took out letters-patent of the United States, Nov. 22, 1864, No. 45,199, for an oscillating engine with an apparently impracticable complication of cams, ratchets, and pawls, to produce automatic variable cut-off, by means of "a centrifugal regulator whose plane of motion is coincident with or parallel to the plane of motion of the adjustable cam operating the induction-valves."

No practical result seems to have followed any of these attempts: the time was not ripe.

Wilson Hartnell and Stair Guthrie, of Lincoln, took out letters-patent of Great Britain, No. 325, of 1868, Jan. 30, for a pair of swinging arms pivoted upon the plate of a case, or upon the arms of a pulley, or balance-wheel, carrying at their free ends weights which

by various devices moved a single slotted eccentric across the shaft, in a direction parallel to a line joining the forward and backward position of the centre of the eccentric.

In one form, a vibrating arm, pivoted at one end to the case, carried at the other end a slotted eccentric, swung backward and forward across the shaft by the centrifugal action of the governor-balls and the centripetal action of springs. In another form, there is a rectangular dovetailed block formed on the end of the hub of a fly-wheel or other pulley, to guide the slotted eccentric in its transverse motion across the shaft.

A year later, May 26, 1869, Richard Roby and John Richardson, of Lincoln, took out letters-patent of Great Britain, for a marine governor mounted on the crank-shaft of a steam-engine, and connected, by means of a rod running through the hollow shaft, with a pair of wedges similar in form to Dodds and Owen's, but wholly different in combination, in function, and in operation.

Instead of moving the slotted eccentric in a direct line from its centre to the centre of the shaft, Roby and Richardson's device moved it from the forward position directly towards the reverse position, as did Hartnell and Guthrie's. Roby and Richardson's slotted eccentric was moved on a square boss on the shaft, between collars fixed to the shaft, like Dodds and Owen's. A cut and description of a portable engine with this device was published in "Engineering," Vol. , p. .

In 1870 E. R. and F. Turner of Ipswich made a portable engine with a slotted eccentric on a square shaft between fixed collars, which was moved square across the shaft by means of opposed wedges, resembling Dodds and Owen's in form, and similar to Roby and Richardson's in form and function, but different in combination.

Instead of the marine governor of Roby and Richardson, E. R. and F. Turner employ an ordinary vertical revolving pendulum governor to control the eccentric through the wedges, by means of a combination of levers and a sort of bell-crank. This engine is described in "Engineering," Vol. X., p. 462.

In 1872 the same E. R. and F. Turner exhibited at the Cardiff Exhibition of the Royal Agricultural Society, a portable engine with a Hartnell and Guthrie governor, having a slotted eccentric carried on the free end of a vibrating link. This engine was entered for competition at the famous competitive trials of portable engines, but was ruled out by an accidental defect, the loosening of a fly-wheel.

Next in order of time, comes the patent granted to J. C. Hoadley, Oct. 28, 1873, and an important improvement June 29, 1875.

A frame secured to the crank-shaft, having suitable gibs and adjusting screws, replaced the square boss on the shaft, to guide the slotted eccentric in its transverse motion. A pendulum, or vibrating arm, pivoted to the fly-wheel, and carrying a slotted eccentric at its free extremity (Hartnell and Guthrie's device), since successfully worked out by others, was tried and abandoned, as too unstable without a dash-pot.

Leaf, elliptic springs placed on opposite sides of the shaft, with their ends connected by links adjustable in length, were carried in sliding spring-pockets upon radial arms set at right angles to the motion of the eccentric, to which motion was given through toggle-joints.

The springs and spring-pockets formed part of the governor-weights; and other weights were provided, to adjust (in conjunction with the strength of the springs and the tension put on them by the links) the governor to the normal speed at which the centrifugal force of the revolving-weights and the resilience of the springs would be in equilibrium.

A single piston-valve received from the eccentric, by the operation of this governor, motions almost identical with those produced by a well-adjusted shifting-link; giving invariable lead, and variable cut-off, release, and compression. Regulation was therefore effected by changes on both sides of the piston, — by changes of working-pressure on one side, and of counter-pressure on the other; or by variable quantity of steam admitted to the cylinder, and by variable working-capacity of cylinder.

A great number of these engines are in use, and they have been often tested. An official test of a common, commercial, portable engine, 14.5-inch cylinder and 20-inch stroke, with naked boiler and unclothed steam-jacket casing, was made at the Centennial Exhibition in Philadelphia, in 1876, by Charles E. Emery and Charles T. Porter, with an efficient corps of assistants.

The coal used was ordinary anthracite, egg-size, such as was used for all the boilers at the Exhibition, without selection or drying, and was, in fact, brought to the door in open wheelbarrows through the rain. An account of the trial will be found in the general report of the judges of Group XX., International Exhibition, Philadelphia, 1876 (J. B. Lippincott & Co., Philadelphia, 1878), pp. 152–158.

A few items of the results are subjoined: —

| | | |
|---|---|---|
| Indicated power | i.h.p., | 80.20 |
| Dynamic power | d.h.p., | 72.72 |
| Steam per indicated horse-power per hour | lbs., | 19.38 |

| | | |
|---|---|---|
| Steam per dynamic horse-power per hour | lbs., | 21.40 |
| Water per indicated horse-power per hour | lbs., | 25.61 |
| Water per dynamic horse-power per hour | lbs., | 28.27 |
| Coal per indicated horse-power per hour | lbs., | 3.35 |
| Coal per dynamic horse-power per hour | lbs., | 3.69 |
| Combustible per indicated horse-power per hour | lbs., | 2.95 |
| Combustible per dynamic horse-power per hour | lbs., | 3.26 |
| Coal consumed per square foot of fire-grate area, per hour | | 21.07 |
| Water evaporated from 183° F., under 120 pounds per square inch above atmosphere, per pound of coal | | 7.65 |
| Do., per pound of combustible | | 8.68 |
| Equivalent evaporation at actual steam-pressure, 135 pounds absolute, from 212° F., per pound of coal | | 8.62 |
| Do., per pound of combustible | | 9.78 |

*The Cummer Engine Company*, Cleveland, O., manufacture an automatic cut-off engine, with flat "gridiron" slide valves, and uninterrupted valve-connections.

The main steam-admission valves are thin, having no "cup" for exhaust, and have at each end three openings for the passage of steam, corresponding to three ports in the valve-face. They are placed against a vertical face in the upper part of a divided steam-chest on the side of the horizontal cylinder, receive motion from an invariable eccentric, and carry upon their backs riding-valves, thin, flat, 2-ported gridiron, and unbalanced, controlled by a governor placed on the eccentric-shaft.

This is not the crank-shaft, but a short shaft near it, parallel with it, and receiving from it synchronous motion by means of a pair of equal spur-gears and an intermediate. The exhaust-valves are also flat, thin, gridiron slides, placed horizontally low down at the side of the cylinder, below the steam-admission and cut-off valves, partly in the space beneath the curve of the cylinder, and are moved by an invariable third eccentric.

The eccentric which moves the riding cut-off valves is turned on its shaft by a centrifugal governor of novel and interesting construction. The shaft which carries the eccentrics and the governor is hollow, and has within it a rod fitted to slide freely endwise. At one end, this rod is connected, by means of a cross-bar extending through a slot in the shaft, with the swinging arms of a governor, so that the governor gives endwise motion to the rod within the shaft. At its opposite extremity, this rod bears against the face of the upright arm of a bell-crank, which is weighted on its horizontal arm; the weights, which are adjustable, acting against the centrifugal force of the "flying weights" of the governor.

By this arrangement, the governor may be adjusted to any normal speed by merely adding or removing weights, which are suspended below the floor of the engine-room, from the horizontal arm of the bell-crank; and the whole system is neutral, and easily controlled by the governor.

Increased centrifugal force readily moves it in the direction of earlier cut-off; and the increased resilience of a supplementary spring, acting with the constant force of the adjusted weights, holds this centrifugal force in check. The governor is therefore at once sensitive and stable.

The swinging arms of the governor, by means of connecting-rods attached to lugs on the cut-off eccentric, turn this eccentric on its shaft, to advance or retard the cut-off according to the requirements of the load. This would change all the other events also, if there were no other eccentric; but, in fact, release, exhaust-closure, and admission are controlled by the other two eccentrics, so that in these respects the effect of the turning of this eccentric is masked, and cut-off alone is practically varied. These engines are skilfully designed, well made, and bear a good reputation.

*Armington, Sims & Co.*, Providence, R.I., have within a few years attained remarkable success in making automatic cut-off engines, mostly of moderate size, running at speeds as high as 350 revolutions per minute, — largely used in driving dynamos for electric lighting. These engines have a short stroke, an overhung cylinder, a compact and well-designed bed-plate, a single tubular piston-valve, closed at the ends, with a passage through its middle portion between its steam-ports or passages, so that, when taking steam directly at one end of the valve, it is also admitting it indirectly from the other end through the hollow valve, giving rapid admission at the beginning of the stroke, almost as with a gridiron valve.

The cylindrical casings which form the valve-seats are placed near the ends of the cylinder, making the steam-passages short and direct, — in a box steam-chest at the side, with a flat cover, which on removal discloses the valves and valve-seats, and facilitates the setting of the valve. Double crank-disks are used, for the most part, and two overhung fly-wheels with belt face.

The governor, a modification of Hartnell and Guthrie's, presents considerable novelty, and possesses no little merit. The single eccentric is composite, consisting of one eccentric within another. The inner one, with large eccentricity, barely encloses the engine crank-shaft; the outer one, of less eccentricity, free to turn upon the inner

one as this is to turn upon the shaft, carries an ordinary eccentric-strap connected by suitable rods with the valve.

The swinging arms of the governor are so connected with these two parts of the eccentric, as to cause them to revolve in opposite directions. When the flying-weights are out, in the position due to the highest admissible speed, and the centripetally opposing springs are most compressed, the two parts of the eccentric are so related that the eccentricity of the inner part is diminished by the whole eccentricity of the outer part, and the movement of the valve is reduced to the sum of its lap and lead, and cut-off is at its shortest; just steam enough being admitted, and just enough exhausted, to keep the engine running at normal speed without resistance other than its own internal resistances.

In the other extreme position of the flying-weights, when the resilience of the compressed springs has brought them, by reason of their slightly diminished speed, back to their most central position, the eccentricity of the outer part of the eccentric is diminished only in part by that of the inner one, and the motion of the valve is increased so as to delay the cut-off to about seven-tenths of the stroke, and release and compression are delayed in equal measure.

This is accomplished by turning the inner part of the eccentric about 55 degrees in one direction, and the outer part simultaneously about 28 degrees in the other direction, — about 83 degrees of relative motion; all by the same motion of the swinging arms.

The combination of these two motions maintains an unaltered linear lead of the valve, and at the same time performs in a faultless manner the function of guiding the eccentric in the transverse motion of its centre. It also combines great delicacy of movement with great stability of position, and all its rubbing surfaces are best arranged for exclusion of dust and continuity of lubrication.

No provision is made for keeping the piston-valve tight, save by reaming out the valve-seat and putting in a new valve, — not a bad way, when all is said.

In point of elegant simplicity these engines are very striking.

*A. L. Ide*, *Springfield*, *Ill.*, has recently brought out an engine which presents some interesting features. The bed-plate, a sort of trough set on its side, partly embraces the crank-disk, contains the slides, which are very wide segments of a cylinder, and is straight on top from the main bearing of the crank-shaft to the overhung cylinder. The cap of the main bearing is set at an angle of about 30

degrees with the vertical, as in the Hoadley portable engines, and in some marine engines.

A single large, hollow piston-valve, with packing-rings at its wearing-faces, is placed directly under the cylinder, and runs in steel bushes inserted in the steam-chest, which is cast in one piece with the cylinder.

The bushes have several bars across their ports, to keep the packing-rings of the piston-valves from spreading into the ports; and, as a further safeguard, the rings are made wider than the ports. Steam is admitted to the steam-chest around the middle portion of the valve, and to the cylinder at the inner edges of the sliding-faces; but at only one end of the valve at the same time, and exhaust takes place through the hollow cylindrical valve.

The governor is a clever and successful modification of Hartnell and Guthrie's slotted eccentric on the free end of a pendulous arm, pivoted at the other end to the case, and controlled in position by two long, curved swinging arms carrying adjustable weights, restrained by long spiral springs, which are extended when the arms are moved out by the weights.

A straight bar, extending from one of these swinging arms to the other, connects them in such a manner as to form a parallel motion, and to cause them to co-operate in moving the slotted eccentric across the shaft.

A dash-pot, connected with the free end of one of the swinging arms, integrates all momentary impulses, and gives steadiness to the governor. Motion is communicated from the eccentric to the valve by a rocker-shaft and arms, as in a locomotive.

The writer has never seen this engine; but the published cuts of diagrams are excellent, and the clear, full, and sensible description of the engine given in Mr. Ide's trade circular evinces careful study and skilful adaptation.

*B. F. Sturtevant*, Boston, well known as a manufacturer of fan-blowers, makes an automatic cut-off engine of no little merit. Its most marked characteristic, aside from its compactness and evident serviceableness, is a novel and peculiar form of "riding-valve," almost frictionless, under the control of a very powerful governor on the crank-shaft, producing a regularity of speed sensibly perfect.

The main valve is long, as the ports are straight, and thick enough to admit cups for exhaust, and is balanced by rings on its back. The passages in this valve, for the admission of steam to the cylinder, do not extend through the entire thickness of the valve, as

is usually the case where a riding-valve is used; but resemble the exhaust-cups, except that they are only as wide as the ports in the cylinder.

Two piston-valves, placed side by side within the thickness of the main valve, receive from the variable cut-off eccentric a differential movement relatively to that of the main valve, such that they are withdrawn just before the beginning of the stroke, opening the passage through the main valve into the cylinder, and returned at the dictation of the governor to close the passages and cut off the steam.

These piston cut-off valves have very little motion in their seats, and are subject to no lateral pressure, and must suffer but little from wear. At the same time a little leakage past them would cause only very slight loss. It could take place only during expansion before the closure of the port by the lap of the main valve, that is, only in the earlier stages of expansion; and only into the cylinder, never directly into the exhaust.

The cut-off valve-stem passes through the tubular stem of the main valve, which is fitted with a stuffing-box at its outer end, as in the Buckeye engine, which this Sturtevant engine much resembles.

The governor has four heavy weights on four swinging arms co-operating to compress by their centrifugal force two long, powerful springs, and with very slight motion, moderated by a dash-pot, give all requisite movement to the cut-off eccentric, — turning it on the shaft to hasten or retard the cut-off.

The weights are spherical, and are adjustable on the straight, threaded arms by simply turning them, so that the most delicate balancing of the whole apparatus is easily attained.

The steadiness and uniformity of motion obtained in this engine are quite remarkable. Indeed, the Moscrop speed indicator makes a straight and narrow line all day, even with great and sudden variations of load.

*The Ball Engine*, manufactured by the Ball Engine Company, Erie, Penn., one of the latest contributions to this class of engines, having the governor on the crank-shaft, will bring our protracted review of such engines to a fitting close, since it will bring to our notice an interesting novelty.

This is, perhaps, the first successful example of a steam-engine regulated not alone by the quantity of steam admitted to the cylinder and the quantity retained in it at each stroke, as determined by the speed itself, but, conjointly with such regulation, the differential tension of the driving-belt is made to take its part in adjusting the

cut-off eccentric on the crank-shaft, and so in proportioning the effective pressure to resistance of the belt in such a manner as to maintain any predetermined rate of speed, either sensibly uniform under all usual variations of steam-pressure and of load, or either faster or slower according to the adjustment, with higher steam-pressure and lighter load, or with lower pressure and heavier load, or with both load and pressure varying in any degree, — of course, within certain limits in either direction.

For example, mill-stones may be made to run the faster the more rapid the feed, or with perfect uniformity, or in any degree slower, irrespective of all usual variations of initial pressure. To accomplish this, flying-weights on swinging arms pivoted to a fly-wheel, restrained by centripetally acting springs, move a slotted eccentric across the shaft, as in the Hartnell and Guthrie governor; and at the same time another pair of springs, acting against the differential tension of the belt, determine the angular position of the belt-pulley on the shaft, and so directly adjust the eccentric to earlier or later cut-off and compression according to this belt-tension.

The facility of running at higher speed with heavier load may be of little importance, except as it affords the means of attaining a perfectly isochronous rotatory motion. This, it is said, the trace of the Moscrop speed-indicator demonstrates to be attainable in the Ball engine; but better regulation than has been reached by the Sturtevant engine seems hardly possible.

*The Lambertville Iron-works*, Lambertville, N.J., manufacture an automatic cut-off engine of the riding-valve type, with the stem of the cut-off valve passing through the hollow stem of the main valve, as in the Buckeye and Sturtevant engines.

The cut-off has releasing-gear, operated by a sliding bar which receives motion from an invariable cut-off eccentric; and the valve, when released by tappets adjusted by an ordinary vertical revolving-pendulum governor, is closed by the recoil of a compressed spring. The valves are balanced by a peculiar arrangement of plates on their back. Relief-valves are put into both ends of the cylinder, to guard against injury from water.

The published diagrams show a wide range of mean effective pressure, with excellent lines; and the general design of the engine is good. The cut-off valve-gear of this engine seems to be a direct outgrowth of that next to be described, — the Greene engine: with which our notice of engines of this class must close, although others not a few come to mind, and appear to deserve attention no less than

some of the preceding; and some, no doubt, are either unknown to the writer, or have been overlooked.

*Noble T. Greene*, Providence, R.I., was very early in the field with a practicable automatic cut-off engine, — about contemporaneous with Corliss, although the courts, in the litigation between them, awarded the priority to Mr. Corliss. The Greene engine is now built by the Providence Steam-engine Company, after a long interruption by an injunction secured by Mr. Corliss for infringement of his patents, which have now expired.

This engine as now built, after undergoing several alterations of form, appears from a recent trade circular to have, for the smaller sizes, a low, straight frame with a flat top-plate a little higher than the top of the crank-shaft, with the main bearing of the crank-shaft at the end of the frame, and the cylinder secured to the side, with the liberating mechanism of the cut-off valve located on top of the girder, behind the cylinder.

A larger engine has a low bed, or sole-plate, with the cylinder placed on top of it, the pedestal for the main bearing of the crank rising from it, and the slides also set up to a corresponding height. This looks like reversion to an antiquated form. There are four valves, moved by two eccentrics, — the exhaust-valves below the cylinder, to drain off accumulated water, and the steam-induction valves at or near the top of the cylinder. All are flat gridiron slides. All are moved by rock-shafts and arms, — the exhaust-valves by one, the steam-valves by two.

A sliding bar running in guides attached to the side of the cylinder carries two tappets which move up and down in obedience to a common ball-governor suspended by a bracket, and are held up to the position in which they are set by the governor, by spiral springs beneath them.

Each tappet has a vertical outward face, and a top sloping away from this face towards the other tappet. Above, secured on two rock-shafts, are two swinging arms, with pendent extremities fitted to engage with the vertical side of the ratchets, and so to move the valve, and to push down the tappet by its beveled top, when the sliding-bar is moving in the opposite direction.

Since the swinging arms move in a circle, while the sliding-bar moves in a straight line, the engaged tappets and extremities of the swinging arms must sooner or later become disengaged: the sooner, the lower the tappets are depressed; the later, the higher they are raised; and when they are disengaged, the connection between the

eccentric and the valve is broken, the valve is liberated, and closed by the joint action of a weight and of steam-pressure on the area of cross-section of the valve-stem.

This engine bears an excellent although a comparatively limited reputation; and the fact that at least one other concern — the Lambertville Iron-works — has adopted it as a model, is some evidence of merit.

A mere catalogue of names of engine-builders would have no interest or value; and for any thing more, if indeed for so much, there is neither space nor time here.

Steam-pumps can only be mentioned in passing. More is hardly necessary; since the Worthington, Knowles, Blake, Deane, and other American steam-pumps, are not unknown in England.

A valuable class of engines used in steamboats, often with a single paddle-wheel at the stern, upon Western rivers such as the Ohio, which during a part of almost every year are in places very shallow, can only be mentioned. Horizontal, with cylinders about 25 inches in diameter and 8 feet stroke; with poppet-valves moved by cams and levers, using steam of high initial pressure, and revealing by the shrill note of their exhaust a moderate degree of expansion, and running at moderate speed of revolution, though with pretty high piston-speed, — these engines afford a fine example of special adaptation to peculiar conditions.

Portable and semi-portable engines are made in countless numbers; not a few of considerable merit, but for the most part very cheap, and far from economical of fuel.

Straw-burning engines for driving separators are largely used in the vast wheat and rye fields of California, and to some extent in the new North-west, where there is no market and little use for straw; but in other parts of the country, straw is too valuable for other purposes to be used for fuel.

The writer passed the harvest-season of 1877 in the vast wheat-fields of Yolo and Sacramento Counties, California, with a straw-burning, portable, automatic cut-off engine of his own design and construction, conveniently fitted with indicators; and retains pleasant and profitable lessons gained by this experience.

A constant record was kept of the feed-water used and of the grain threshed and cleaned; and diagrams with 30 consecutive lines were taken often enough to give a fair idea of the indicated power developed under various conditions.

The engine, 7.5-inch cylinder-diameter and 10-inch stroke, was known, by experiment, at 250 revolutions per minute, 125 pounds boiler pressure above the atmosphere, and 15 horse-power, to require 30 pounds of feed-water per indicated horse-power and per hour, so that the consumption of feed-water was an approximate measure of the power developed.

Traction-engines, although made to some extent, are yet far less common than in England and elsewhere in Europe. The writer, in the capacity of department judge of Department A, Class 3, at the Ninth Cincinnati Industrial Exposition, in 1881, conducted tests for economy, in the Exposition Building, and for service in the field and on the road, of three traction-engines, made by the Geiser Manufacturing Company, Waynesborough, Penn.; Frick & Co., of the same place; and the Huber Manufacturing Company, Marion, O.

Two other traction-engines were entered for competition, but withdrawn before the trial. A detailed report of these tests may be found in the report of the commissioners of the Ninth Cincinnati Industrial Exposition, and in the "Scientific Proceedings of the Ohio Mechanics' Institute," May, 1882, p. 54.

The two engines first above named were in most respects admirable, and their performance was very good. On the difficult route assigned them, both would have done better if provision had been made for coupling together the two driving-wheels, in order that one, on firm ground, might help the other out of a rut, — this necessary co-operation being cut off by an admirable equalizing gear which rendered the engines very manageable on firm land.

The best economy obtained was 35.1 pounds of feed-water per indicated horse-power and per hour, equal to about 4 pounds of good coal. The best actual result, measured in coal consumed, was 6.13 pounds per indicated horse-power and per hour.

Ploughing-engines, as already said, are little used in the United States. It has been said that the soil in this country, at the season for ploughing, is so dry that dust is a great obstacle to the use of steam ploughing-engines; but a more serious obstacle is probably to be found in the heavy outlay required, and the limited capital at the command of most farmers. The future development of this class of engines is to be expected.

Marine engines must get but cursory notice here. This is the less to be apologized for, inasmuch as Maw's "Recent Practice in

Marine Engineering" is not entirely silent on the subject of recent American marine engines.

If no more successful than the writer in obtaining information from American marine-engine builders, the scant notice will match the scant courtesy.

The most striking novelty is to be found in the torpedo-boat engines and boilers of the Herreshoff Manufacturing Company, Bristol, R.I.; and these are so fully described in Maw's "Marine Engineering," that little need be said here.

The production of 169.47 indicated horse-power in a boat only 48 feet long over all, with engine and boiler only 6,320 pounds weight, including the usual water-supply in the boiler, and a water-tank capable of holding 720 pounds, making the entire weight of engine and boiler no more than 37.17 pounds per indicated horse-power, is certainly noticeable, as is the production of this power with the consumption of only 4.13 pounds of artificial fuel (briquettes) per indicated horse-power per hour.

The ability to make over 100 miles at a speed of more than 16 miles per hour, with no more fuel than its bunkers can stow, is also worth mentioning.

Of curious engines there is no end. Among these the writer places the Westinghouse engine, now much in vogue, and all the rotary engines.

Of these latter, that of Richard Dudgeon of New York is well known, although little used, to the writer's knowledge, out of the shop of its inventor, where one has been running since 1870. An account of this really curious engine will be found in "Engineering," Vol. XVI., p. 398, Nov. 14, 1873.

The rotary engine of Leander J. Wing of Boston is less known. With great ingenuity and equal pertinacity he has brought his engine as nearly to the excellence of a good reciprocating engine as anybody has yet done or is likely to do.

It remains only to say a few necessary words about the American locomotive.

The steady development of this grand machine, by the concurrent efforts of many hundreds of men during more than fifty years, had resulted in a few general styles, so well adapted to the several requirements of ordinary passenger-trains, of express-trains, of freight-trains on moderate grades, and of freight-trains on heavy grades, and the forms and proportions of these several styles had become so well settled, and so firmly established, that a race of

improved human beings constructed on the crustacean instead of the vertebrate plan would have seemed quite as likely as that any marked alteration in the American locomotive could ever be introduced.

The weak point was the narrow fire-box, and the limited fire-grate area, necessitating rapid combustion, no less than 50, 80, 100 pounds, and occasionally 150 to 180 pounds, of coal per hour on every square foot of grate; and to this admitted defect the American bar-truss frame contributed in some small degree.

But the immense advantages of this rigid frame over the flat slab-frame, which must be almost wholly dependent on the boiler for needful stiffness, are so great that it could never have been given up for the sake of less than 10 per cent increase of fire-grate area.

The Wootten locomotive seems to have overcome this difficulty. By raising the fire-grate above the top of the driving-wheels, room is obtained to spread it out to any desirable width; and an area of 68 to 72 square feet, 8 feet wide by 8.5 or 9 feet long, from two to four times as large as could be obtained between the drivers, is provided. The moderate rate of combustion required on this large grate is easily maintained with a gentle blast, and a variable exhaust-nozzle 4 to 5 inches in diameter gives sufficient draught for all occasions.

The result is, that inferior fuel, coal-slack, anthracite or bituminous, or lignite containing 20 per cent of water, can be used successfully, and in the vicinity of coal-mines with great economy; and higher efficiency is obtained from all grades of fuel.

Fired at two doors, and at a convenient elevation above the foot-board, the grates are easily kept clean, and the fire is readily kept in a uniform state.

The large fire-box, with 151 square feet of heating-surface and a combustion-chamber, beyond a bridge-wall of fire-brick, with 32 square feet, present, all together, 183 square feet of most efficient surface, largely exposed to direct radiation from the incandescent solid fuel.

The incidental advantages are equally marked, — comparative immunity from cinders, soot, and smoke, and considerably reduced wear of furnace-plates.

But the most remarkable circumstance is, that raising the centre of gravity is said to have noticeably improved the ease of the engine on the rails, and the steadiness and smoothness of running.

The illustration offered, namely, that a stick loaded at one end can be more easily balanced on the finger with the loaded end upper-

most, may not present a true analogy, but it is perhaps as nearly so as comparison with the stability of a vessel with centre of gravity high or low.

On the 1st of January, 1884, the Philadelphia and Reading Railroad Company report 171 of these engines, using waste anthracite exclusively for fuel, and that 83 per cent of the main-line coal tonnage of the previous year had been moved by locomotives using such waste fuel, resulting in a saving during the year, in that item alone, of $378,000.

The first one constructed had completed its seventh year of service, and had run 183,904 miles in coal and freight train service; yet no evidence of wear or deterioration of fire-box plates was apparent. The mean annual mileage of this engine is 26,272.

Twenty engines in all, put in service between January, 1877, and March, 1881, had each run more than 120,000 miles, 7 on passenger-trains, 2 on freight-trains, and 11 on coal-trains, with a mean annual run of 33,660 miles, without showing any sensible wear of the fire-box plates.

It may be that the experience with these locomotives is yet too slight to warrant safe conclusions as to their permanent qualities; but they appear to constitute one of America's most important contributions toward the improvement and development of the locomotive of the future.

A locomotive built by the Baldwin Locomotive Works of Philadelphia, for the Central Railroad of New Jersey, designed for fast passenger service, will give a fair idea of good American practice. This engine, No. 169, one of four altogether similar, save that two had cylinders 19 by 24 inches, while this and another had cylinders 18 by 24 inches, is fully described and illustrated in "The American Machinist," New York, Jan. 7, 1882.

It has 4 drivers coupled, 68 inches in diameter; rigid wheel base; tread to tread of drivers and of truck-wheels, 7 feet 6 inches; distance from mid-point between drivers to centre of truck, 14 feet 2 inches; truck-wheels 30 inches in diameter; gauge, 4 feet 8.5 inches. A swinging bolster on the truck gives flexibility to the running gear, which carries the weight of the boiler and engines precisely as two independent four-wheeled carriages would carry it.

The fire-box is set on top of the frame, the upper bar of which slopes forward from the top of the jaws of the trailing-wheels directly towards the main driving-axle, and is joined to the after jaw of that axle-box at the middle of its height; and is 3 feet 7.75 inches wide by 10 feet 5 inches long, giving 38 square feet fire-grate area.

The fire-grate is formed of 10 water-tubes 2.25 inches in diameter outside, and 4 solid bars which can be withdrawn for cleaning out clinkers, and has a slope forward of 12 inches, the rear end being a few inches above the bottom of the water-space. The boiler has 200 tubes 2 inches outside diameter, and 11.49 feet long; 145 square feet of heating-surface in fire-box, 1,175 in flues, and 1,320 in all.

The total weight of the locomotive, in working order, is 93,000 pounds, — say 41.52 tons; and normal steam pressure is 140 pounds per square inch above the atmosphere, — say 10.5 atmospheres absolute. The train usually consists of five cars; namely, one baggage-car, one express-car, one Pullman drawing-room coach, and two ordinary passenger-coaches; and schedule time, 37 minutes, is easily made between Jersey City and Bound Brook, 32 miles, — 52.16 miles an hour. This distance has been run in 33 minutes, say at the rate of 58.2 miles an hour.

Three miles upon the route have been run in 2 minutes and 24.5 seconds, and frequently covered in 2.5 minutes; and a single mile has been run in 45 seconds, — timed between mile-posts with a stop-watch. These times correspond to speeds, for three miles, of 74.74 miles and 72 miles an hour; and, for a single mile, 80 miles an hour.

The same builders made in 1883, for the Cantagallo Railway, Brazil, three locomotives, bearing the numbers 28, 29, and 30, of 43½ inches gauge, weighing 40.5 tons in working-order, which draw trains weighing 40 tons up a grade of 8.3 feet in 100 (438.28 feet per mile), with a succession of reverse curves of 131 feet radius, — 43.8 degrees per 100 feet, — by ordinary adhesion alone.

These engines have cylinders 18 by 20 inches; 6 driving-wheels, connected, 39 inches in diameter; wheel base, 9 feet 6 inches; boiler 54 inches in diameter, with 190 flues 2 inches outside diameter and 10 feet 9 inches long, and side tanks carried on the locomotive.

The most notable change that has been made in the American locomotive in the past twenty years has been a gradual increase of weight. On the Pennsylvania Railroad, since 1867, locomotives of the same class have increased in weight from 33 to 35 tons, up to 41 to 45 tons, in working-order. All their engines have air-brakes applied to the driving-wheels, and all their passenger engines are equipped with scoops for picking up water while running.

All their boilers are made of open-hearth steel, fire-boxes included; rivets and stay-bolts of iron. All have water-grates made of tubes 1⅞ inches diameter outside, and ¼ inch thick.

All locomotives have flexible running-gear, by means of the swinging bolster truck. A perfect system of standard dimensions

and interchangeable parts for engines of the same class, greatly reduces the delay and cost of repairs.

Perhaps the most thorough test of locomotive performance in ordinary work, considered merely as a steam-boiler, and a double steam-engine, ever made in the United States, was carried out by Mr. John W. Hill, in July, 1878, on the Cincinnati, Hamilton, and Dayton Railroad, upon a Baldwin engine, No. 36, drawing a train of 35 loaded box freight-cars, and a caboose-car, weighing in the aggregate 649 tons, and with the mean dead load of engine, tender, coal, and water, 50 tons, 699 tons, or 1,565,583 pounds.

A very complete and well-digested account of this test appears in the Journal of the Franklin Institute, Philadelphia, for April and May, 1870; and only a very brief abstract of results can be reproduced here.

At the time of the test, the engine had been out of the builders' shop 22 months, and had run 55,471 miles, and was taken with only ordinary examination and adjustment. The distance from Cincinnati to Dayton, 57.7 miles, was divided into three runs: Cincinnati to Hamilton, 24.7 miles; Hamilton to Twin Creek, 15.9 miles; and Twin Creek to Dayton, 17.1 miles.

The first run was nearly level for about 6 miles, then rose by a nearly uniform grade of 18.2 feet per mile, to a summit 182.14 feet above the starting-point, and then descended 88.15 feet in 8.8 miles to a point 93.99 feet higher than the starting-point, making the mean grade for the 24.7 miles 3.81 feet per mile.

The aggregate curvature on this first run was 315 degrees 32 minutes 15 seconds, a mean of 12 degrees 46 minutes 29 seconds per mile, divided among twelve curves, chiefly of 1 degree, having a mean radius of 5,032 feet.

The second run presented a nearly uniform grade of 6.68 feet per mile, rising 106.26 feet in 15.9 miles, making the total net ascent in 40.6 miles, 200.25 feet. The aggregate curvature on this second run was 105 degrees 15 minutes, a mean of 6 degrees 37 minutes 10 seconds per mile, divided among three curves of 1 degree, and one of 0 degree 50 minutes, having a mean radius of 6,115 feet.

The third run rises with a nearly uniform grade of 3.84 feet per mile, 65.61 feet in the 17.1 miles, gaining an altitude of 265.86 feet above the starting-point in 57.7 miles, a mean (net) of 4.608 feet per mile. The aggregate curvature on this third run is 256 degrees 54 minutes, a mean of 15 degrees 2 minutes 28 seconds per mile, divided among six curves, mostly of 1 degree, having a mean radius of 4,831 feet.

Considered as a whole, the route presented an aggregate curvature of 677 degrees 41 minutes 15 seconds, a mean of 11 degrees 44 minutes 42 seconds, per mile, with a mean radius of 5,124 feet.

The first run was made in 1 hour and 26 minutes, at the rate of 17.23 miles per hour; but the first 15.9 miles occupied about 1 hour and 7 minutes, a speed of about 14.2 miles per hour, and the 8.8 miles down grade was made in about 19 minutes, — a speed nearly double, 27.8 miles per hour.

The second run — heavier in grade but easier in curvature — was made in 42 minutes, at the rate of 23.67 miles per hour, an increase of speed of 37.4 per cent, obtained at great cost of fuel.

The third run occupied 50 minutes, at a speed of 20.5 miles per hour. The whole distance, 57.7 miles, was run in two hours and 58 minutes, running-time, at a mean speed of 19.45 miles per hour.

Sets of diagrams were taken from both ends of both cylinders at regular intervals of 2 minutes, — 40 sets during the first run, 20 during the second, and 21 during the third run. Twelve selected sets of these diagrams are published, and show excellent valve-adjustment.

Every diagram — 324 in number — was separately computed for power, and expenditure of steam, the power ranging from 725.94 indicated horse-power on up grade at high speed, to 30.64 indicated horse-power on down grade, at low speed; and the results are tabulated separately for each cylinder, and for each run. A condensed summary is subjoined.

| | First Run. 24.7 Miles. | Second Run. 15.9 Miles. | Third Run. 17.1 Miles. |
|---|---|---|---|
| Boiler-pressure | 122 | 124 | 123 |
| Revolutions per minute | 100.473 | 124.129 | 133.25 |
| Initial pressure | 98.542 | 107.096 | 105.516 |
| Cut-off, in terms of stroke | .5276 | .5149 | .5290 |
| Release, in terms of stroke | .8787 | .8761 | .8716 |
| Terminal pressure | 43.579 | 44.989 | 43.690 |
| Counter pressure | 2.380 | 5.924 | 6.186 |
| Exhaust closure, in terms of return stroke | .7552 | .7454 | .7499 |
| Mean effective pressure | 64.946 | 64.179 | 63.200 |
| Mean indicated horse-power | 291.96 | 368.66 | 388.50 |
| Steam per indicated horse-power per hour, pounds computed from diagrams | 27.46 | 26.88 | 26.57 |

CONDENSED SUMMARY (*Concluded*).

| | First Run. 24.7 Miles. | Second Run. 15.9 Miles. | Third Run. 17.1 Miles. |
|---|---|---|---|
| Feed-water per indicated horse-power per hour, pounds | 32.28 | 33.40 | 31.96 |
| Ratio of steam to water | .8507 | .8027 | .8319 |
| Coal per indicated horse-power per hour, pounds | 4.238 | 7.033 | 5.359 |
| Coal with uniform evaporation of 9 pounds of water per pound of coal per indicated horse-power per hour, pounds | 3.586 | 3.711 | 3.551 |
| Coal burned per square foot of fire-grate area per hour, pounds | 83.91 | 171.82 | 117.27 |
| Evaporation per pound of coal | 7.07 | 4.51 | 6.22 |
| Equivalent evaporation from and at 212° Fah. pounds of water per pound of coal | 8.36 | 5.34 | 7.30 |
| Mean temperature of feed-water, degrees Fahrenheit | 78.5° | 77.0° | 86.3° |

The leading dimensions of boiler and engines are given below.

Fire-box, 63 inches long, 34.5 inches wide, 60.5 inches high. Barrel, 10 feet 8 inches long, 48 inches in diameter. Flues, 138, 2 inches outside diameter, 11 feet long. Heating-surface, square feet fire-box, 93.85, tubes 794.82, front tube-sheet 10.00, aggregate 898.67.

Fire-grate area, 15.09 square feet; ratio of heating-surface to fire-grate area, 59.65 to 1.

Engines: cylinders, 16-inch diameter, 24-inch stroke; piston-rods, right-hand 2.75 inches, left-hand 2.8125 inches diameter; mean net area of pistons, right-hand 198.09 square inches, left-hand 197.91 square inches; clearance in terms of stroke, .076.

Gauge, 4 feet 8.5 inches; diameter of the four driving-wheels coupled, 61 inches; driving-wheel base, 8 feet; whole length of wheel-base, 22 feet; total weight of engine with two gauges of water, 32.24 tons (72,220 pounds). Weight on driving-wheels, 20.02 tons (44,840 pounds).

The consumption of water above given includes all that was blown off at the safety-valve, and used at the whistle and gauge cocks, and in experiments with a calorimeter. Allowing for these losses, Mr. Hill estimates the quantity used by the engine cylinders in producing power, at 30.02, 31.05, and 29.72 pounds per indicated horse-power per hour, respectively, for the three runs.

At all events, the performance of the engines considered by themselves was highly satisfactory. The coal was Pittsburgh No. 2, screened and picked, supposed to be the best available at Cincinnati.

With a pressure at release of 44 to 45 pounds, and a back-pressure on the pistons of 5 to 6 pounds per square inch above the atmosphere, the loss by unconsumed coal blown out at the smoke-stack must have been considerable, and may have been, as Mr. Hill estimates, 20 per cent, or more. But this only sets in a clearer light the inadequacy of the fire-grate area.

With a grate as in the Wootten engine, four and a half times as large, the highest rate of combustion would have fallen, with equal coal-consumption, from 172 to 38.2 per square foot of fire-grate per hour, and might well have been reduced, through increased economy, to 20 pounds.

On a portion of the first run, from observation 12 to observation 31, the engine ran, in 38 minutes, 8.8614 miles up an incline nearly uniform, of 18 67 feet per mile, equal to 1 in 283, gaining an elevation of 165 44 feet, at the rate of 14 miles per hour.

The total weight of the train at this point was a little over 700 tons, say 1,568,000 pounds, and the absolute lift in 38 minutes was, when reduced to dynamic horse-power, —

$$\frac{1{,}568{,}000 \times 165.44}{38 \times 33{,}000} = 206.87 \text{ d. h. p.}$$

The mean indicated horse-power during this same period of 38 minutes, deduced from 19 sets of diagrams, was 312.37. The difference, 312.37 − 206.87 = 105.5, which is 33.77 per cent of the gross indicated horse-power, represents all the resistances of train and engine other than the dead lift.

Mr. Hill estimates the internal resistances of the locomotive, from experiments made with it when run without load, at average speed, — "diagrams taken as fast as possible," — as equal to 33.384 indicated horse-power, which, divided by 312.37, gives 10.66 per cent; and the additional frictions of the engine, due to the load, at 5 per cent of the remainder, and .05 (100 − 10.66) = 4.46. The sum, 10 66 + 4 46 = 15 12 per cent, represents the engine resistances; and this subtracted from the gross resistances, 33.77 per cent, leaves 18.65 per cent of the mean indicated power for train-resistances proper, other than the dead lift, equal to 28.16 per cent of the power expended in the dead lift itself.

This is undoubtedly too little, as it gives only 2.414 pounds resistance per ton, say $\frac{1}{927.9}$. If we assume that the descending grade

compensates for an equal height of ascending grade, we have 93.99 feet rise in 24.695 miles, and the co-efficient of resistance becomes 6.62 per ton, say $\frac{1}{338.4}$. All the data of the three runs are brought together in the following table: —

| No. of Run. | Tabular Nos. of Diagrams Taken. | Distance Run, in Miles. | Mean Curvature; Degrees per Mile. | Total Net Rise, in Feet. | Total Mean Indicated Power, Indicated horse-power. |
|---|---|---|---|---|---|
| I. . . . . | 13 to 31 | 8.86 | 14° 48′ | 165.44 | 312.37 |
| I. . . . . | 1 to 40 | 24.695 | 12° 46′ | 93.99 | 291.96 |
| II. . . . | 1 to 20 | 15.87 | 6° 37′ | 106.26 | 368.66 |
| III. . . . | 1 to 21 | 17.08 | 15° 25′ | 65.61 | 388.50 |
| I., II., III.. | | 57.645 | 11° 45′ | 265.86 | 337.17 |

| No. of Run. | Resistance of Locomotive; indicated horse-power. | Friction of Locomotive due to Train Resistance; indicated horse-power. | Net Power Applied to Train; dynamic horse-power. | Dead Lift of Train; dynamic horse-power. | Resistance of Train on a Level; dynamic horse-power. |
|---|---|---|---|---|---|
| I. . . . . | 33.38 | 13.95 | 265.04 | 206.55 | 58.49 |
| I. . . . . | 33.38 | 12.93 | 245.65 | 48.17 | 197.48 |
| II. . . . | 33.38 | 16.77 | 318.51 | 120.21 | 198.30 |
| III. . . . | 33.38 | 17.76 | 337.36 | 62.19 | 275.17 |
| I., II., III.. | 33.38 | 15.19 | 288.60 | 65.83 | 222.17 |

| No. of Run. | Resistance of Train in Pounds per Ton, $r$. | Ratio of Resistance to Weight of Train. | No. of Run. | Resistance of Train in Pounds per Ton, $r$. | Ratio of Resistance to Weight of Train. |
|---|---|---|---|---|---|
| I. . . | 2.414 | $\frac{1}{927.9}$ | III. . . | 7.754 | $\frac{1}{288.9}$ |
| I. . . | 6.620 | $\frac{1}{338.4}$ | I. . . | 7.260 | $\frac{1}{308.5}$ |
| II. . . | 5.051 | $\frac{1}{443.4}$ | II. . . | | |
| | | | III. . . | | |

The total resistance of the locomotive, ascertained by experiment to be equal to 33.38 indicated horse-power, which is 9.9 per cent of the mean total indicated power (337.17 indicated horse-power), is made up of two parts: first, the resistance of the wheels on the rails, which, at its mean value, 6.688 pounds per ton $\left(\frac{1}{334.9}\right)$, amounts to 17.23 indicated horse-power, equal to 5.11 per cent, leaving 16.15 indicated horse-power, equal to 4.79 per cent of the total mean indicated horse-power, as the sum of the internal frictions of the engine when propelling only itself and its tender, 49.174 tons, at mean velocity. The respective speeds were: for part of the first run, No. 13 to No. 31, ascending grade 18.21 feet per mile, 14 miles per hour; for the entire first run, ascending 182.14 feet, then descending 88.15 feet, net rise 93.99 feet, mean grade 3.809 feet per mile, 17.23 miles per hour; second run, ascending grade 6.683 feet per mile, 22.67 miles per hour; third run, ascending grade 3.837 feet per mile, 20.496 miles per hour. The mean speed, mean net rising grade 3.809 feet per mile, was 19.431 miles per hour. These figures indicate that the rolling resistance of this train was less than it is given in D. K. Clark's tables, than which nothing is more likely. But this whole subject has been too little studied, and the writer has devoted to this trial more time than he could have done if it were not almost alone in this field.

Some examples of locomotive performance, which the writer has taken no little pains to verify, will close this portion of our subject.

Locomotive No. 137, Boston and Albany Railroad, built in the repair-shop of the company at Boston, under the charge of Mr. George H. Colby, division master mechanic, was placed in service April 23, 1883, and after running seven days to Worcester, 44 miles and return, making 616 miles, was put, on April 30, into regular express-train service between Boston and Springfield, making the round trip in 6 hours, about 3 hours each way. The distance, commonly called 100 miles, is, by measurement, 98.63 miles, making the round trip 197.26 miles. She continued in this service until July 10, 1884, 14 months and 11 days, say 438 days, with the loss of only 2 days for trivial repairs, — in one case, the tightening of an eccentric, — but made some extra runs, so that her mileage was in all 87,190 miles, making her daily mean for the 438 days 197.65 miles, at the rate of 72,192 miles per annum; and for the 436 days of actual service, 198.11 miles. On the 10th July, 1884, she was taken into the shop; and in the four days, July 11, 12, 14, 15, without any work on nights or on Sunday, her tires were turned, her valves faced,

and all parts were put in perfect order, including painting and varnishing all over; and on the 16th she resumed her regular service.

The road is very crooked, and presents curves of 573 feet radius (10° curves); and although the western end of the route is only 60 feet higher than the eastern end, the rise to the summit, 57.25 miles from Boston, is 893 feet, and the descent thence to Springfield, in 41.38 miles, is 833 feet, making the mean rising grade, going west, 15.5 feet per mile, and going east, 20.13 feet; and there are several inclines, 3 to 5 miles in length, of 38 to 60 feet per mile. The train comprised 2 baggage and express cars, 4 sleeping-cars, and 3 to 5 first-class long passenger-cars, usually weighing and often exceeding 300 tons, — say 672,000 pounds, locomotive and tender included. From May 1, 1883, to July 1, 1884, a period of 14 months (427 days), this engine has a record of 84,596 miles, — 427 round trips, with a total consumption of coal equal to 1,965.625 tons, 4.603 tons per round trip, 52 pounds per mile, 0.1733 pounds per ton per mile, 1,718.6 pounds per hour, and a mean per hour, on each square foot of grate — up grade and down grade — of 95.48 pounds. The power could not have been less, as a mean, than 340 indicated horse-power, rising at times, probably, to 600; and the mean consumption of coal was about 5 pounds per indicated horse-power and per hour.

The oil used for lubrication, in the same period, was 1,120.5 gallons, equal to 75.51 miles per gallon; and the cost of oil and waste was $622.55, equal to 0.736 cent per train-mile, and repairs would not bring the aggregate up to 1 cent. Coal was taken at Boston for the round trip. At the exorbitant price of $5 per ton, the cost of fuel per train-mile was about 11.6 cents, and per mile-ton, 0.039 cent. There are seven engines of this description now in use on this road, and others in construction. The leading dimensions are as follows: Cylinders, 18 inches diameter, 22 inches stroke; 4 driving-wheels connected, 68.75 inches diameter, 100 inches centre to centre; total wheel-base, 22 feet $4\frac{5}{16}$ inches. Boiler, wagon-top, barrel 52 inches diameter outside of small courses, $\frac{7}{16}$ inch thick, flue-sheets $\frac{1}{2}$ inch, fire-box $\frac{5}{8}$ inch, all Nashua Company's steel; 221 semi-steel tubes, 2 inches outside diameter, 10 feet $10\frac{1}{4}$ inches long between tube-sheets, $\frac{5}{8}$ inch apart; fire-grate area, 18 square feet; heating surface, in fire-box 130 square feet, flues inside 1,140 square feet, total 1,270 square feet. Total weight, 87,000 pounds (38.839 tons); weight on drivers, 55,000 pounds (24,554 tons); normal pressure, 160 pounds per square inch above the atmosphere, say 11.88 atmospheres, absolute.

The "Pacific," built by the Lawrence Machine Shop, of which

the writer was superintendent, was placed in service on the Boston and Maine Railroad, April 16, 1855, and continued to run regularly double round trips between Boston and Lawrence, distance 26 miles, daily, except Sundays, or on other equivalent routes, until the close of 1883, a period of 28 years 9½ months. The record, subsequent to 1876, was destroyed by fire a year ago; but one book escaped, which shows when this engine was in the repair-shop, and the amount of repairs upon her, from the start, down to Dec. 23, 1873, 18.8 years. The superintendent of repairs on this road, Mr. William Smith, ran the "Pacific" thirteen and a half years, making an aggregate mileage, during that time, of 417,879 miles. Mr. Smith is perfectly familiar with her performance since 1873; and from information obtained from him, and from the record, which I have transcribed, it appears that

| | |
|---|---|
| Her total mileage on passenger-trains, in 28.8 years, was . . . | 891,475 |
| And her subsequent mileage on gravel-trains, to Aug. 1, 1884, is | 12,780 |
| Total mileage . . . . . | 904,255 |

She has had one new fire-box, and one new set of flues, and other extensive repairs, and is now in good serviceable order; and more than one-half of the weight of the original material originally put into her is in her to-day. This engine has outside connections, shifting link valve-gear, cylinders 15 inches diameter, 22 inches stroke, 4 connected drivers 66 inches diameter, and a centre-bearing truck. Total weight 27.5 tons, weight on driving-wheels 17 tons. Price, in dear times, $8,500, say £1,756.

The statement summarized below, of the performance of three locomotives on the Hudson River Division of the New York Central and Hudson River Railroad, was kindly furnished to the writer by Mr. William Buchanan, superintendent of motive-power of that division.

The three engines, designated as No. 10, No. 33, and No. 34, are of the following general dimensions: Cylinders, 17 inches diameter, 24 inches stroke; driving-wheels, 69 inches diameter; fire-boxes of steel, flues of semi-steel; weight in running order, 31.473 tons (70,500 pounds); weight on driving-wheels, 20.022 tons (44,850 pounds); average trains, 2 baggage and mail cars 52 tons, 2 drawing room or sleeping cars 64 tons, 5 first-class passenger-cars 125 tons, engine 31 tons, tender, half loaded, 22 tons; total, 294 tons. Average speed of trains, 38 miles per hour. Period of time covered, 6 years, from December, 1876, to December, 1882, for No. 10 and No. 33; and from March, 1877, to March, 1883, for No. 34.

PERFORMANCE: No. 10.

| | |
|---|---|
| Total mileage in 6 years | 488,900 |
| Number of days in service | 1,766 |
| Number of days idle | 400 |
| Number of months actually in service | 71 |
| Average number of miles per day | 276.84 |
| Average number of miles per month | 6,886 |
| Average number of miles per annum | 81,483.33 |
| Gallons of oil used | 3,413 |
| Average number of miles per gallon | 143.24 |
| Total cost of oil | $1,391.00 |
| Total cost of waste | 290.00 |

## COST OF REPAIRS.

LABOR: No. 10.

| ITEMS. | On Engine. | On Tender. |
|---|---|---|
| Machinist | $3,372.46 | $60.90 |
| Blacksmith | 442.64 | 61.87 |
| Boiler-maker | 1,336.57 | 42.68 |
| Coppersmith | 58.19 | - |
| Tinsmith | 30.34 | - |
| Carpenter | 162.95 | 67.44 |
| Painter | 330.76 | 64.30 |
| Total labor | $5,733.91 | $297.19 |

MATERIALS: No. 10.

| ITEMS. | Engine. | ITEMS. | Tender. |
|---|---|---|---|
| Machinery | $1,138.70 | Iron | $36.32 |
| Tire | 230.00 | Trucks | 690.30 |
| Trucks | 508.00 | Lumber | 20.00 |
| Boiler and flues | 1,259.40 | Paints | 49.20 |
| Lumber | 43.33 | | |
| Paints | 100.54 | | |
| Materials | $3,279.97 | Materials | $795.82 |
| Labor, brought down | 5733.91 | Labor, brought down, | 297.19 |
| Total, engine | $9,013.88 | Total, tender | $1,093.01 |
| Repairs of engine, brought down | | | 9,013.88 |
| Total repairs of engine and tender in 6 years | | | $10,106.89 |
| Repairs per annum | | | 1,684.48 |

PERFORMANCE: No. 33.

| | |
|---|---|
| Total mileage in 6 years | 523,393 |
| Number of days in service | 1,865 |
| Number of days idle | 307 |
| Number of months actually in service | 70 |
| Average number of miles per day | 280.64 |
| Average number of miles per month | 7,477 |
| Average number of miles per annum | 87,232.17 |
| Gallons of oil used | 3,954 |
| Average number of miles per gallon | 132.37 |
| Total cost of oil | $1,609.00 |
| Total cost of waste | 288.00 |

## COST OF REPAIRS.

LABOR: No. 33.

| ITEMS. | On Engine. | On Tender. |
|---|---|---|
| Machinist | $3,615.73 | $101.51 |
| Blacksmith | 527.41 | 136.03 |
| Boiler-maker | 1,228.72 | 86.47 |
| Coppersmith | 57.01 | - |
| Tinsmith | 47.17 | - |
| Carpenter | 210.30 | 55.66 |
| Painter | 296.97 | 105.83 |
| Total labor | $5,983.31 | $485.50 |

MATERIALS, No. 33.

| ITEMS. | Engine. | ITEMS. | Tender. |
|---|---|---|---|
| Machinery | $1,310.51 | Iron | $193.51 |
| Drivers | 32.00 | Trucks | 878.00 |
| Tire | 231.00 | Lumber | 44.40 |
| Trucks | 590.39 | Paints | 59.00 |
| Boiler and flues | 1,269.91 | | |
| Lumber | 80.67 | | |
| Paints | 143.31 | | |
| Materials | $3,657.79 | Materials | $1,174.91 |
| Labor, brought down | 5,983.31 | Labor, brought down | 485.50 |
| Total, engine | $9,641.10 | Total, tender | $1,660.41 |
| Repairs of engine, brought down | | | 9,641.10 |
| Total repairs, engine and tender, in 6 years | | | $11,301.51 |
| Repairs per annum | | | 1,883.58 |

PERFORMANCE: No. 34.

| | |
|---|---|
| Total mileage in 6 years | 468,173 |
| Number of days in service | 1,700 |
| Number of days idle | 492 |
| Number of months in actual service | 69 |
| Average number of miles per day | 275.40 |
| Average number of miles per month | 6,785 |
| Average number of miles per annum | 78,028.83 |
| Gallons of oil used | 3,634 |
| Average number of miles per gallon | 128.83 |
| Total cost of oil | $1,475.00 |
| Total cost of waste | 282.00 |

## COST OF REPAIRS.

LABOR: No. 34.

| ITEMS. | On Engine. | On Tender. |
|---|---|---|
| Machinist | $3,855.05 | $68.35 |
| Blacksmith | 480.61 | 61.52 |
| Boiler-maker | 1,216.43 | 83.42 |
| Coppersmith | 82.73 | – |
| Tinsmith | 34.83 | – |
| Carpenter | 193.60 | 86.04 |
| Painter | 336.32 | 112.54 |
| | $6,199.57 | $411.87 |

MATERIALS: No. 34.

| ITEMS. | Engine. | ITEMS. | Tender. |
|---|---|---|---|
| Machinery | $1,659.58 | Iron | $77.48 |
| Drivers | 67.00 | Trucks | 631.25 |
| Tire | 231.00 | Lumber | 40.00 |
| Trucks | 447.50 | Paints | 66.80 |
| Boiler and flues | 1,018.00 | | |
| Lumber | 56.89 | | |
| Paints | 163.78 | | |
| Materials | $3,643.75 | Materials | $815.53 |
| Labor, brought down | 6,199.57 | Labor, brought down | 411.87 |
| Total, engine | $9,843.32 | Total, tender | $1,227.40 |
| Repairs of engines, brought down | | | 9,843.32 |
| Total repair, engine and tender, in 6 years | | | $11,070.72 |
| Repairs per annum | | | 1,845.12 |

## MEAN OF ALL.

PERFORMANCE: No. 10, No. 33, and No. 34.

| | |
|---|---|
| Mean mileage in 6 years | 493,489 |
| Number of days in service | 1,777 |
| Number of days idle | 399.67 |
| Mean number of months in service | 70 |
| Mean number of miles per day | 277.63 |
| Mean number of miles per month | 7,049 |
| Mean number of miles per annum | 82,248.11 |
| Mean number of gallons of oil used | 3,667 |
| Mean number of miles per gallon | 134.81 |
| Mean total cost of oil | $1,491.67 |
| Mean total cost of waste | 286.67 |

## MEAN COST OF REPAIRS.

LABOR: No. 10, No. 33, and No. 34.

| ITEMS. | On Engine. | On Tender. |
|---|---|---|
| Machinist | $3,614.41 | $76.92 |
| Blacksmith | 483.55 | 86.47 |
| Boiler-maker | 1,260.57 | 70.86 |
| Coppersmith | 65.98 | - |
| Tinsmith | 37.45 | - |
| Carpenter | 188.95 | 69.71 |
| Painter | 321.35 | 94.22 |
| | $5,972.26 | $398.18 |

## MEAN COST OF MATERIALS.

No. 10, No. 33, and No. 34.

| ITEMS. | Engine. | ITEMS. | Tender. |
|---|---|---|---|
| Machinery | $1,369.60 | Iron | $102.44 |
| Drivers | 33.00 | Trucks | 733.18 |
| Tire | 230.67 | Lumber | 34.80 |
| Trucks | 515.30 | Paints | 58.33 |
| Boiler and flues | 1,182.44 | | |
| Lumber | 60.30 | | |
| Paints | 135.88 | | |
| Materials | $3,527.19 | Materials | $928.75 |
| Labor, brought down | 5,972.26 | Labor, brought down | 398.18 |
| Total, engine | $9,499.45 | Total, tender | $1,326.93 |
| Repairs of engine, brought down | | | 9,499.45 |
| Mean total repairs, engine and tender, in six years | | | $10,826.38 |
| Mean cost of repairs, per annum | | | 1,804.39 |

MEAN COST PER TRAIN-MILE OF LABOR AND MATERIALS ON ENGINE AND TENDER, ON No. 10, No. 33, AND No. 34, DURING SIX YEARS, IN CENTS AND FRACTIONS OF A CENT.

| | No. 10. | No. 33. | No. 34. | Mean. |
|---|---|---|---|---|
| Machinists | .70 | .72 | .84 | .75 |
| Blacksmiths | .11 | .13 | .12 | .12 |
| Boiler-maker | .28 | .25 | .30 | .28 |
| Copper and tinsmith | .02 | .02 | .02 | .02 |
| Carpenter | .05 | .05 | .06 | .05 |
| Painter | .08 | .08 | .09 | .08 |
| Total, labor | 1.24 | 1.25 | 1.43 | 1.30 |
| Materials | .84 | .93 | .95 | .90 |
| Total, repairs | 2.08 | 2.18 | 2.38 | 2.20 |
| Oil | .28 | .30 | .32 | .30 |
| Waste | .06 | .05 | .06 | .06 |
| Total, cents | 2.42 | 2.53 | 2.76 | 2.56 |

These engines were new at the beginning of the period covered by the record here reproduced, and the cost of repairs must increase with increasing age. Indeed, compared with a like statement for the first five years, the mean annual mileage is 1.2 per cent less, and the cost of repairs is 23 per cent greater, while oil and waste are almost exactly the same per train mile, both in quantity and in value.

Some information which was hoped for, to afford a broader basis for estimates of the performance of American locomotives, their durability, and the cost of repairs upon them, cannot now be obtained in season for this occasion. The examples presented are, it is admitted, selected examples, and must be above the mean, taking age into consideration, if nothing more; but so much has been done, and, accident and misfortune apart, can be done generally with engines of like age.

With compound locomotives, little has been done in this country. A few have been constructed, but without any very marked success, so far as the writer has been able to learn. It is certainly very desirable to reduce the consumption of fuel in our locomotives; but if compounding involves of necessity the use of a cranked-axle, as in some examples, it can never be adopted in America, since the well-known evils of that feature must far outweigh all possible gain from compound cylinders. The locomotive engine is without doubt the

most important application of the non-condensing engine of Oliver Evans and the multi-tubular boiler of Nathan Read, and its development demonstrates that it has not been neglected in the land of its nativity.

With a few words about prices now current, this too protracted paper will be brought to a close. The weight of our ordinary American locomotive, with cylinder 17 inches diameter, and 24 inches stroke, four driving-wheels connected, 5 feet diameter, is about as follows: —

| Loaded: 2 Gauges of Water. | | | Light. | |
|---|---|---|---|---|
| Tons. | Pounds. | | Pounds. | Tons. |
| 22.991 | 51,500 | On drivers . . . . . | 46,000 | 20.536 |
| 12.589 | 28,200 | On truck . . . . . | 24,000 | 10.714 |
| 35.580 | 79,700 | Total, engine . . . . . | 70,000 | 31.250 |
| 25.446 | 57,000 | Tender, 3,000 gallons capacity . | 24,000 | 10.714 |
| 61.026 | 136,700 | Engine and tender . . . . . | 94,000 | 41.964 |

Price, with steel boiler, head-light included, $6,500, or, say £1,343; per ton, $154.89, equal to £32; per pound, 6.91 cents, equal to 3.43 pence.

Engines of various sizes and styles may be bought about at prices subjoined, which, it must be said, are about the actual cost.

| Cylinders. | | Styles. | Prices. | |
|---|---|---|---|---|
| Diameter. | Length of Stroke. | | Dollars. | Pounds Sterling. |
| 16 | 24 | 4-wheeled switching . . . . . | 5,500 | 1,136 |
| 15 | 24 | 8-wheeled . . . . . | 5,500 | 1,136 |
| 16 | 24 | 8-wheeled . . . . . | 6,000 | 1,240 |
| 17 | 24 | 8-wheeled . . . . . | 6,500 | 1,343 |
| 18 | 24 | "Mogul," freight . . . . . | 7,300 | 1,508 |
| 20 | 24 | Consolidation, freight . . . . | 9,000 | 1,860 |

The "Mogul" engine has six driving-wheels connected, with a single pair of pilot-wheels, swinging bolster, and radius bar. The

"Consolidation" engine has eight driving-wheels connected, with a single pair of pilot-wheels, swinging bolster, and radius bar. In both, a part of the weight otherwise carried by the pilot-wheels is transferred to the driving-wheels by equalizing levers.

The prices above given are certainly too low, as they afford no satisfactory profit to the manufacturer.

# SECTION E.

# GEOLOGY AND GEOGRAPHY.

25362

# ADDRESS

BY

PROF. N. H. WINCHELL.

VICE PRESIDENT, SECTION E.

## *THE CRYSTALLINE ROCKS OF THE NORTHWEST.*

I DESIRE to call the attention of Section E to some of the interesting problems that beset the geologist who undertakes to study the crystalline rocks of the Northwest, and especially that part of the Northwest which is included in the state of Minnesota. Until very recently it has been the practice of geologists, almost without exception, to refer every crystalline rock in the Northwest either to the Huronian or to the Laurentian. Thus, when the survey of the state of Michigan was reinaugurated in 1869, the geologists of the upper peninsula were compelled to choose between a confession of their inability to establish the age of the rocks they were studying and the adoption of some of the recognized designations. In Wisconsin the case was similar, with the additional fact that the Michigan geologists were collaborators. The same was true again in Minnesota. What more natural than that the Michigan and Wisconsin rocks should be found to extend, with nearly the same features, into the State of Minnesota, and that their familiar names should at once be applied to them?

But when on more careful examination, both in the field and in the literature of the crystalline rocks, and over a wider extent of territory, and especially in the light of more recent researches in New England, New York, Pennsylvania and Canada, it is found that the nomenclature is imperfect, and furnishes but a tottering scaffold to support the workmen of a great and ever-spreading structure, we are thrown into such difficulty and doubt that we are prone either to reject the old scaffold and build anew, or to clear away the accumulated rubbish about the foundation and examine on what basis the old one stands. To-day, however, we intend to do neither of these, but rather set forth a few of the incongruities and difficulties of the actual situation.

We are indebted, unquestionably, to the geologists of Michigan and Wisconsin for the most exhaustive and satisfactory description of the crystalline rocks of the Archæan age that has yet been published in America. In order that some of the difficulties of the situation may be made clear, I desire to review concisely the broad stratigraphic distinctions of the crystalline rocks that have lately been studied in Michigan, Wisconsin and Minnesota. By the aid of the published results of the surveys of Brooks, Wright, Irving, Rominger, Pumpelly and others, a generalized statement can be formulated. To these I shall add such published results and unpublished field observations from Minnesota as may be furnished by the survey of that state, in order that the scheme may cover correctly the crystalline rocks of the entire Northwest.

Omitting the igneous rocks, which in the form of dikes cut through the shales and sandstones of the Cupriferous formation and are interbedded with them in the form of overflows, we may concisely arrange the crystalline rocks, disregarding minor differences and collating only the broad stratigraphic distinctions, in the following manner in descending order:

There are six groups:

### First Group.

*Granite and gneiss with gabbro.*—This group is represented in Minnesota by the gabbro and red syenite at Duluth, and by the extension of this range of hills northeastwardly nearly to the international boundary. Its thickness is unknown, but certainly reaches several hundred feet. The outcrop of red granite near New Ulm, lying under the conglomerate and red quartzite, is probably in the southwestward line of extension of this group. This group is represented by No. xx southwest of lake Michigamme, by No. xx at Menominee and by No. 1 and 1a at Black river.

### Second Group.

*Mica schist.*—This group consists of schists that are micaceous and often staurolitic as well as garnetiferous. It can be seen in Minnesota on the Mississippi river at Little Falls, and at Pike rapids. The schists are variously associated with beds and veins of granite and gneiss. This is No. xix at Marquette, xvii to xix

at Menominee, XX to XXII at Penokee, and has a maximum thickness of 5000 feet.

### THIRD GROUP.

*Carbonaceous and arenaceous black slates, and black mica schists.*—These sometimes pass into roofing slates, with beds of iron ore, quartzite and diorite. This group includes the black slates of the Animikie group in northern Minnesota, of Knife lake, and Knife portage on the St. Louis river, and carbonaceous slates lately reported near Aitkin on the Mississippi river. It includes Nos. XIV to XVII at Marquette, Nos. VI to XVII at Penokee, and Nos. XV and XVI at Menominee. Thickness 2600 feet.

### FOURTH GROUP.

*Hydro-mica and magnesian schists.*—Soft and obscure, becoming quartzose and also hæmatitic, also with numerous beds of diorite. In Minnesota this is the iron-bearing horizon at Vermilion lake. It is Nos. VI to XIV at Marquette, Nos. IV to VI at Penokee, and Nos. VI to XI at Menominee. Maximum thickness 4450 feet.

### FIFTH GROUP.

This is the group of *gray quartzite and marble.* It is represented by No. V at Marquette, Nos. II to V at Menominee and Nos. I to III at Penokee. In Minnesota this horizon seems to run along the south side of Ogishke Muncie lake, near the international boundary, and perhaps includes the great slate-conglomerate which is there represented. Normal thickness from 400 to 1000 feet; but if the great conglomerate of Ogishke Muncie be included here, the thickness of this group in northern Minnesota will exceed 6000 feet.

### SIXTH GROUP.

*Granite and syenite with hornblendic schists.*—This lowest recognized horizon has frequently been styled Laurentian. In Minnesota it is found on the international boundary at Saganaga lake, and large boulders from it are included in the overlying conglomerate at Ogishke Muncie lake, showing an important break in the stratigraphy. Thickness unknown but very great.

These six great groups compose, so far as can be stated now, the crystalline rocks of the Northwest. Their geographic relations to the non-crystalline rocks, if not their stratigraphic, have been so well ascertained, that it can be stated confidently that they are all older than the Cupriferous series of lake Superior, and hence do not consist of nor include metamorphosed sediments of Silurian or any later age.[1]

This statement of the grand grouping of the crystalline terranes of the Northwest may be varied by the addition of detailed and minor distinctions and by subdivisions, but its correctness rests upon careful observations and reports of competent geologists, and cannot at present be gainsaid.

Examining these groups more closely we find:

I. We have, beneath the red tilted shales and sandstones, a great *granite and gabbro group*. This has been variously regarded by different geologists. While by many early observers it was classed as older than the series which has latterly been designated Huronian, and by others styled igneous and local, it has, by Brooks, been placed with that series and denominated "the youngest" of the Huronian strata, though no such rocks had ever before been mentioned as pertaining to the Huronian. By Irving it has been made the base of his Kewenawan. By Hunt it has been parallelized with the Montalban. It includes, in my opinion, the felsites and porphyries which have been styled Arvonian, and it is very certain that in many places it has passed for typical Laurentian. The gabbro is very generally admitted to be of eruptive origin, and in its great development in Canada it was once styled Upper Laurentian, and later was known as Norian. While the gabbro is certainly eruptive, the associated granite and gneiss exhibit evidences of being metamorphic in their nature. In northern Minnesota this horizon of granite is characterized by a red color and it has an aggregate chemical composition almost identical with that of some of the associated felsites. The magnetite of the gabbro is often highly titaniferous and so abundant that the rock has attracted attention as an iron ore. The gabbro does not always appear where the granite is present, but extensive areas of granite are spread out without any sign of variation, interruption or alternation with the gabbro. In other places these

[1] The term Silurian here is understood to cover nothing below the base of the Trenton.

two rocks are intricately and intimately mingled both horizontally and perpendicularly; but the gabbro may be considered in general as the underlying formation. Both these rocks seem to have been molten, and simultaneously so, in some places; but in the great mass of the red, granitic rock, there is a gneissic structure, and in its finely crystalline state, when it seems to vary to felsite, it exhibits a laminated structure which is evidently due originally to sedimentation. Along these laminations, and coincident with them, is a finely lined striation which exhibits the "streamed" structure, sometimes appealed to, to show the igneous nature and origin of the rock. These felsites are occasionally arenaceous, with irregularly rounded or sub-angular quartz grains, and sometimes are porphyritic with quartz and orthoclase. Veins of red granite intersect the gabbro, and the gabbro surrounds isolated masses of the granite. Transported, boulder-like masses of both are found embraced in a common paste among the later igneous outflows of the Cupriferous, where their existence is as great a puzzle as that of pebbles of red felsite and quartz-porphyry in the red conglomerates. This red granite, so far as I have observed, generally consists largely of orthoclase, and in several instances passes imperceptibly into red felsite. It contains also quartz and hornblende, the latter generally changed by decay. The gabbro, when unaffected by proximity to the red rock, consists of the three essential ingredients: labradorite, diallage and magnetite, with some necessary products of alteration, but in the vicinity of contact with the red rock it also holds orthoclase and quartz.

II. Below this granite and gabbro group is a series of strata that may be designated by the general term *mica schist group*. This is the principal, but not the only, horizon in which mica schist exists. This division is penetrated by veins and masses of red biotite-granite which appear to be intrusive in somewhat the same manner as the red granite in the gabbro overlying. However, whether this granite is exotic, or can be referred to aqueo-igneous fusion and transmission of the sedimentaries in a plastic state through fissures in the adjacent formations, is a question which still is a matter of earnest investigation. The existence of the great associated igneous gabbro is suggestive, if not demonstrative, of the presence of an adequate agent for such a metamorphism—unless it be claimed, indeed, that such an extravasation of molten rock could take place without any marked and traceable effect on

the contiguous formations. These granite veins penetrate only through the overlying gabbro and this underlying mica schist. They are wanting or comparatively rare throughout the rest of the crystalline rocks. On the other hand there is an abundance of diabase and other doleritic rock, in the form of dykes, throughout all the crystalline strata. This points to the mere local nature of the origination of these granitic veins, and hence to the metamorphic nature of the granitic mass with which they are connected. It has been shown by Dana that granite suffers a change to mica schist in western Massachusetts; Brooks as well as Emmons has shown it interstratified with limestone in St. Lawrence county, New York. They both also state that the Potsdam sandstone becomes gneissic. The same has been affirmed in Vermont by Dr. Hitchcock, and by Dr. Frazer in Pennsylvania. Hence there is no impropriety in supposing that some great change has passed over the sedimentary strata of this horizon throughout a wide extent of country reaching from the Atlantic to lake Superior, and that in the emergences of upheaval and dislocation the sediments of one formation were enabled to penetrate transversely into the strata of another.

This mica schist formation has an aggregate thickness of about 5000 feet, and sometimes is hornblendic rather than micaceous.

III. The next lower grand division, which is the third, might be styled the *black mica slate group*. This group contains much carbon, causing it to take the form of graphitic schists, in which the carbon sometimes amounts to over forty per cent.[2] These schists are frequently quartzose, and also ferruginous, even composing valuable ore-deposits, as at the Commonwealth mine in Wisconsin. Associated with these black mica slates, which often appear also as dark clay-slates, are actinolitic schists, the whole being, in some places, interstratified with diorite. Their estimated thickness is 2600 feet.

IV. Underneath this is a very thick series of obscure, *hydromicaceous and greenish magnesian schists*, in which, along with beds of gray quartzite, and clay slates, occur the most important deposits of hæmatitic iron ore. The lower portion of this series, which at Marquette is represented rather by hornblende and chloritic quartz-schists, and more rarely is mined as a magnetic quartz-

[2] A recent analysis of a specimen from near Aitkin, Minnesota, showed between forty-two and forty-three per cent of carbon.

schist, at Penokee is known as "the magnetic belt." This division of the crystalline rocks has numerous heavy beds of diorite.

V. Below this series of soft schists, which terminate downward with the magnetic iron ores, is the great *quartzite and marble group.* The marble lies above the quartzite, and in the Menominee region has a minimum thickness of at least one thousand feet; while at Marquette it graduates into a dolomitic quartzite of indefinite extent, the whole group there being essentially a quartzite. This is a most persistent and well-marked horizon. The quartzite sometimes holds feldspar, thus having an appearance of granulite. In northern Minnesota, the great slate-conglomerate of Ogishke Muncie lake seems to represent the lower portion of the great quartzite of this group, and to be the equivalent of the lower slate-conglomerate of the "typical Huronian" in Canada. In both places this conglomerate is sometimes speckled with masses of red jasper. The marble of this group appears adjacent to the conglomerate south of Ogishke Muncie lake, and in such a position as to overlie it, exposing a thickness of at least twenty-two feet.

Now, the difficulties of the situation arise when we cast about to find names for these parts. What are the eastern representatives of these western groups, and by what designations shall they be known?

Since the geological survey of New York, and the publication of its final report, the progress of geological science in Europe and America has rendered it necessary to revise some of the dogmas which were regarded as fundamental by the New York geologists, and to reject entirely some others. Among these may be mentioned the then current theory that the term "primary" should be applied to any massively crystalline rock, and that all such rocks belong to the bottom of the chronological scale of geology. If the apparent structural relations of the formations, as seen in the field, did not agree with this theory, some violent movement in the earth's crust was at once conjectured so as to bring nature into accordance with the true theory. Latterly, however, it has been shown abundantly by Dana and others, that the Trenton, Hudson River and other Silurian rocks are converted into crystalline schists; by Whitney that the Tertiary rocks become crystalline; by Brooks and Frazer that the Potsdam sandstone becomes gneissic; by Reusch that the clay slates, interbedded

with the granites and gneisses of the Bergen peninsula of Norway,[3] contain characteristic Upper Silurian fossils, and by Hitchcock that the Helderberg rocks of New York are involved in the crystalline terranes of New Hampshire.

These more recent crystalline series, however, may all be considered as excluded from the scope of search for any parallels to the crystalline groups of the Northwest. Our inquiry will involve only the well-known names Laurentian, Huronian, Taconic, Montalban, Arvonian, Norian.

We meet at the outset with the question which has now become as historic in American geology as the Cambro-Silurian controversy in England, and which concerns very nearly the same geological horizon, viz.: Is there a formation such as claimed by Emmons—the Taconic? On this geologists are yet divided. We conceive, however, that the division is caused, not so much by doubt as to the existence of a sedimentary fossiliferous formation below the New York system, and separating it from the "primary," as by doubt as to which and how many of these sub-Silurian strata are to be included in the designation of Taconic. Having now however, given the subject very careful consideration, I am ready to state my very positive conviction that Dr. Emmons was essentially right, and that the Taconic group will have to be recognized by geologists and adopted in the literature of American geology.

Dr. Emmons, in 1842, issued the first that appeared of the volumes of the final report of the New York survey. In that volume he formally sets forth the Taconic system, although, as he admits, in an imperfect manner, the area in which the rocks exist not being in his (the second) district. In this first presentation of the system he extended it geographically too far east, and unfortunately chose a name for it which is appropriate only to a part of that eastward extension. We are indebted to the researches of several volunteer geologists, Wing, Dana, Dale, Dwight, for the disentanglement of the overlying Hudson River rocks from the true Taconic rocks, and the demonstration of the incorrectness of Dr. Emmons' eastward extension of his system in southern Vermont. Dr. Emmons' claim, however, in all its essential points, remains intact. This consists in the existence of a series of sedimentary deposits, largely metamorphic, below the Potsdam sand-

[3] Lesley, Report C⁴.

stone, and separating the Potsdam from the crystalline rocks known as "primary," in an orderly chronological scheme.

In his report on the agriculture of New York, issued four years after that on the geology of the second district, he makes more definite and convincing statements, going over the whole subject *de novo*. He gives diagrams showing the Taconic slates lying below the Calciferous sandrock unconformably, at Whitehall in Washington county, a region that had been colored by Mather and Hall on their geological maps as Hudson River, and lying in the general area described by Emmons as Taconic. He gives one also from the hills of Greenbush, opposite Albany, not far from the locality in which Mr. Ford has since discovered primordial fossils, where he also shows the Calciferous lying unconformably upon the Taconic, the former being fossiliferous. He also describes the Hudson River slates as lying unconformably on the Taconic, a fact which cannot be called in question since the recent discoveries of Wing, Dale, and Dwight, and the stratigraphic investigations of Dana. In fact, the investigations of these geologists, instead of destroying the Taconic system, are only confirmatory of the published statements of Dr. Emmons in 1846.

Although the existence of the Taconic in Maine and Rhode Island, as claimed by Dr. Emmons, may not be maintained by further research, it is certain that he had the approval of Dr. Douglas Houghton in extending it into the state of Michigan. In later years, he also traced these rocks through Pennsylvania and Virginia into North Carolina. In Michigan his identifications have since been set aside and the same rocks have been denominated Huronian by Brooks, Wright, Irving and others. In North Carolina Mr. Kerr has, in the same way, substituted the name Huronian. The conclusive fact that these slates had been seen, by Dr. Houghton, in many localities, to pass beneath the Potsdam sandstone, was considered ample to supply the only important point of evidence lacking in the Hudson valley. Dr. Emmons closes his discussion by stating his theme thus, referring to the facts obtained from Dr. Houghton: "It would be difficult to add to the weight of this testimony in regard to the separate and independent existence of a system of fossiliferous rocks, of an age anterior to the Silurian or New York system."

It is not necessary to refer to the controversies that arose from the creation of the imaginary Quebec group, nor to char-

acterize in deserved terms the attempt to bury the Taconic in the Quebec coffin. It is not necessary to quote the support which Emmons had from Barrande, nor to recount the discoveries of Mr. Ford nor the observations of Brooks in St. Lawrence county, N. Y., and Rogers in Pennsylvania, though these last both affirm that beneath the Potsdam sandstone are extensive beds of semi-crystalline strata.[4]

There may be reasons why the current literature of American geology is almost silent respecting the great work of Emmons, and why the Taconic is not known among the recognized geological formations; but we have nothing to do with these at this time. We have to say now only that it seems necessary to admit that when Dr. Emmons insisted on a great group of strata belonging to the age of the Lower Cambrian, lying below the Potsdam sandrock in New York, he had some foundation more substantial than imagination or mere hypothesis. He may have chosen an unfortunate designation, he may have but imperfectly understood the extent and importance of his discovery, and he may have incorrectly described its range and scope, but none of these faults, nor all of them, should deprive him of the credit of having made the discovery. He did more, he defended it to the last day of his life, and averred that "the Taconic system stands out as boldly as the Carboniferous."[5] The argument against the Taconic system, which appeals to imperfect or incorrect definition by its author, will apply with equal force against the Silurian system and also against the Cambrian; also against the Huronian and the Laurentian, and perhaps with still greater force against the Hudson River, since none of these were correctly and properly defined at first by their authors.

If the equities of geological nomenclature, in the light of the results of later researches, demand of geologists of this generation a fair consideration of the claims of Dr. Emmons, that consideration must be granted. No amount of error, though heaped to the sky and supported by the highest authority, can long subsist. The truth, though tardy in asserting itself, will finally throw off the burdens under which it labors, and will shine the brighter for the darkness which preceded it.

If we examine the descriptions, given by Dr. Emmons, of his

[4] Address of H. D. Rogers, 1844, before the Assoc. Amer. Geol. and Nat.
[5] Letter to Jules Marcou, dated Raleigh, N. C., Nov. 6, 1860.

Taconic system, we shall find that he makes the following broad stratigraphic distinctions.

I. His highest member is what he designates *black slate*, which he declares, in some cases, plunges apparently beneath the "ancient gneisses" and contains a considerable amount of carbonaceous matter. In this slate, at Bald mountain, were found two genera of primordial trilobites that were described by Dr. Emmons: the much buffeted *Atops trilineatus*[6] and *Elliptocephala asaphoides*.

II. Under the black slate his next grand distinction was the so-called *Taconic slate*, which he described as argillaceous, siliceous and "talcose," the upper part being suitable for roofing and other portions adapted for flagging. It is greenish, grayish and sometimes of a chocolate color. Its grain is very fine, but in some places it is arenaceous rather than argillaceous. Thickness about 2000 feet.

III. Below this great mass of soft schists, he described, in the first place, a mass of 500 feet of limestone, designated "Stockbridge limestone," which graduates downward into "talcose" or magnesian sandstones and slates, the whole having a thickness of about 1700 feet.

IV. Under this limestone is his "granular quartz rock," more or less interstratified with slates, and becoming, in some places, an immense conglomerate with a "chloritic paste." In this conglomerate are fragments of the underlying gneiss, or

V. A formation which constituted, in his scheme, the "ancient gneiss" on which the Taconic system was said to lie unconformably.

Now it requires but a glance to perceive how closely this order coincides with that which has been independently and laboriously worked out in the Northwest. We have in both instances a "black slate" which in one case is said to be at the top of the system, but to pass apparently beneath the "ancient gneisses," and in the other is reported to be overlain by a group of mica schist and the "youngest Huronian," a mass of gneiss and gabbro. Below the black slate in both cases is an immense series of soft, hydro-mica and magnesian schists. These again are followed by limestone which in the Northwest often forms marble, and in

[6] According to Mr. Ford this is *Conocoryphe*.

New England sustains extensive marble quarries. This has various transitions to slate and to a hard sandrock, but in both places it becomes known, in its lower portions, as a great bed of quartzite; and finally at the base is coarsely conglomeritic with masses of rock from the great underlying series of gneiss. Were there no other precedent this very parallelism would be taken at once as demonstrative, or at least indicative, of equivalence of age. The "Stockbridge limestone," however, at Stockbridge, seems to be of the Trenton age, according to Professor Dana; and where it appears in the Taconic mountains, farther south and west, it is assumed by him to be of the same formation. But no one can affirm safely that the Taconic range of mountains is made up of the Trenton and Hudson River formations till the crucial test has been applied to them successfully in the discovery of the characteristic fossils, and assuredly not, in the absences of this test, in the face of the foregoing parallelism with a limestone known to lie much lower; and in the face of the discovery of primordial fossils in Bald mountain some miles further north in Washington county, New York. It is to be remembered, also, that the schists of Mt. Washington are distinctly different from those of southern Vermont containing the Trenton fossils found by Mr. Wing, "a change" taking place in them not far south from the point at which the fossils were found, continuing thence to the southern extremity of Mt. Washington.[7]

Now, however, we are confronted with another difficulty. The geologists of Michigan and Wisconsin have set aside Dr. Emmons' identification of the Menominee rocks with the Taconic in 1846, and have called them Huronian, the same that has been done in North Carolina by Mr. Kerr, parallelizing them with the Canadian system, which in 1855 was so named by Dr. T. Sterry Hunt.[8]

It becomes necessary, therefore, to ascertain of what the Huronian consists. Dr. Hunt sets out with the statement that it was designed to include the younger and unconformable series of metamorphic rocks found on the shore of lake Huron and in the valley of the Thessalon river, "and also the so-called volcanic formations of lake Superior." Thus the avowed intent was the same as that of Dr. Emmons in erecting the Taconic system.

[7] Dana, *Amer. Jour. Sci.* (3), XVII, 376.
[8] Equisse geologique du Canada; Azoic rocks, Rep. E, p. 72.

If we seek for the actual stratigraphic and mineralogical characters of these rocks, we shall find them in the geological reports of the Canadian survey, particularly that of 1863.

In descending order the original Huronian consists of the following strata, disregarding the diorites and other "greenstones," all of which are thought by Logan to be of igneous origin, though included in the thicknesses given.

| | | |
|---|---|---|
| White quarzite | 400 | feet. |
| Limestone | 200 | " |
| White quartzite | 1500 | " |
| Limestone, siliceous and cherty | 400 | " |
| White quartzite | 2970 | " |
| Red jasper conglomerate | 2150 | " |
| Red quartzite or conglomerate | 2300 | " |
| Slate conglomerate | 3000 | " |
| Limestone | 300 | " |
| Slate conglomerate | 1280 | " |
| White quartzite | 1000 | " |
| Chloritic and epidotic slates | 2000 | " |
| Gray quartzite | 500 | " |
| Total | 18000 | " |

Of this series of 18,000 feet, 900 feet consist of limestone; 2000 feet consist of "chloritic and epidotic slates," and 15,100 feet consist of quartzite and conglomerate. Perhaps 5000 feet of this last thickness may be considered intrusive, consisting of diorite and other forms of "greenstone." This will leave 10,000 feet, at least, for the aggregate thickness of quartzite and conglomerate, being nearly double that observed in the same horizon in northern Minnesota.

It is plain to see that if there be any parallelism between these beds and the various groups made out in the Northwest, the whole of these strata must be made the equivalent of Group v, or the *quartzite and marble group*. The 2000 feet of chloritic and epidotic slates, represented as near the base of the original Huronian, followed as they are by an immense thickness of conglomerate and slate-conglomerate, are anomalous unless there be below them other slate-conglomerates. This, indeed, is very probable, since on the shore of lake Superior, near the mouth of the river Doré, according to the same authority, the lowest part of the Huronian is seen to consist of a green slaty conglomerate, containing "boulders" of granite and gneiss.

The extension of the term Huronian from the horizon of the

original Huronian, upward through the overlying groups, may be justified by the expression of the original intent in the application of the term, but it certainly does not seem warranted by any description of rocks by the Canadian geologists, nor by any claim that usually has been put forth by the authors of the name.

There is, therefore, a conflict between the Taconic and the Huronian, both in respect to the horizon which they are intended to cover (both being referred by their authors to the Lower Cambrian) and in the horizon of rocks which they actually compass. The Huronian, however, in its original and typical description, can be parallelized with only the very lowest of the strata that were included in the typical and original Taconic; while the Taconic stretches upward at least as far as to include the fourth and third grand groups made out in the Northwest, that is to say, the *hydro-mica and magnesian schists*, and the *carbonaceous and arenaceous black slates.*

This leaves two series of rocks untouched by the scope of either the Huronian or the Taconic, as these systems were at first defined, namely: the *mica schist group*, and the *granite and gneiss with gabbro group.* In the term *Montalban* proposed for these groups by Dr. Hunt, the two are united and the constant distinctness which they seem to maintain is not recognized. The granite and gabbro group has affinities with the overlying *Cupriferous rocks*, and perhaps, as Irving has suggested should be considered the base of that series which Brooks has named "Kewenawian," whereas the mica schist group has affinities with the underlying groups, and has, without exception, been assigned to the same system and age as those underlying groups. The granite and gabbro group has likewise been designated differently. The gabbro, being an igneous rock, varies much in its prevalence and in its apparent relation to the granite. Its greatest development produces in Minnesota a range of low hills which extend northeastward from Duluth. Under similar circumstances, this group has received the name *Norian*, though at first called *Labradorian*, and thought to be a part of the Laurentian.[9] The granite and gneiss, also, associated with the gabbro, have received, under one of their modified conditions, the special designation *Arvonian*, on the supposition that these rocks where they so appear, are not modified conditions

[9] It was described by Emmons under the term "Hypersthene rock."

of granite and gneiss, but represent independent strata that lie near the bottom of the "Huronian," equal in rank to any of the other groups. I think I have shown elsewhere[10] that the Arvonian rocks of lake Superior are interstratified with the Cupriferous, and also that they are modified sediments of the Cupriferous. Instead of being near the bottom of the "Huronian" in the Northwest, they overlie all the other groups that have been assigned to the Huronian by Irving, and constitute a part of the great series of "younger gneisses" which by Brooks has been ranked as the "youngest Huronian."

The interesting variety of nomenclature, as brought out by the foregoing remarks, can be seen by a glance at the accompanying tabular arrangement, where the various parallelisms and the conflicting nomenclature are placed in adjoining columns.

It is evident from this table that at present it is a hazardous, and perhaps an impossible, undertaking to assign the groups of the crystalline rocks of the Northwest to any of the terranes that have been named further east, without violating somebody's system of nomenclature. Some of the ground has been covered several times by different names, but on different hypotheses of structure, origin, and parallelism. Respecting the horizon known as "Laurentian" there is an approach to unanimity and agreement. This, however, consists more in a tacit consent to style the lowest known rocks Laurentian, than in any agreement among geologists as to the nature and composition of the strata. The Taconic of Emmons, which has been buffeted and combated from the day of its birth, has from that very circumstance been generally ignored by geologists, because of a certain air of dubious authenticity which accompanies the word. The term Huronian has been allowed to stand and to flourish, partly because of the high authority on which it rests and the remoteness and inaccessibility of the typical locality, and partly, at first because of the non-publication of Dr. Emmons' protestation that it was the equivalent of some part of his Taconic, and later, because, after Emmons' death, as well as before, his opponents were active in spreading views adverse to the Taconic system throughout the literature of American geology. The original Huronian has grown from the dimensions of a single group (the quartzite and marble group), so as to

[10] A. A. A. S. Cincinnati meeting; Minnesota Survey, Rep. for 1880, p. 36; *ibid.*, 1881, p. 110.

include all the crystalline rocks lying above that group, spreading from the Laurentian to the unchanged sediments of the Upper Cambrian. This has become so obviously wrong, in some cases, and has included groups of rocks so plainly extra-Huronian, that a double and triple nomenclature has been applied to a part of these upper rocks, for the purpose of relieving the term of the heterogeneous burden which it was otherwise compelled to carry. These new names, with the exception of the Montalban, seem to be of value only as regional designations, the strata which they represent being igneous or metamorphic, and hence liable to be wanting in some places and to be non-crystalline in others. They further complicate the stratigraphic nomenclature, since the strata are probably only the locally modified parts of the same system. Their geographic distribution in the Northwest not only indicates their stratigraphic horizon, but also their limited and local existence.

In conclusion, the chief points brought out in this discussion may be stated more concisely:

1. The crystalline rocks of the Northwest are comprised under six well-marked comprehensive groups.

2. The Taconic of Emmons, so named in 1842, and more correctly defined in 1846, included three of these groups.

3. The Huronian of Canada is the equivalent of the lowest of the Taconic groups, and the perfect parallel of only the lowest of the groups in the Northwest that have been designated Huronian.

4. The uppermost of the groups in the Northwest is local in its existence, and exceptional in its character, and has received therefore a variety of names.

5. There are, therefore, confusion and conflict of authority in the application of names to the crystalline rocks of the Northwest.

| GROUPS. | EMMONS. | HUNT. | BROOKS. | IRVING. | EQUIVALENTS IN MICHIGAN. | EQUIVALENTS IN WISCONSIN. | EQUIVALENTS IN MINNESOTA. |
|---|---|---|---|---|---|---|---|
| GROUP I. Granite and Syenite with Gabbro. | Hypersthene Rock. (Regarded as part of the Primary.) | Montalban. Labradorian Norian. Upper Laurentian. Arvonian. | Youngest Huronian. | Base of the Keweenawan. | XX. | I and Ia at Black river. | Duluth. Brulé mountain. Misquah hills. Beaver Bay. |
| GROUP II. Mica Schist. | | | The Huronian of Brooks. 1873. | The Huronian of Irving. 1879. | XIX at Marquette. XVII-XIX at Menominee. | XX-XXII at Penokee. | Little Falls. Pike Rapids. Outlet of Vermilion lake. |
| GROUP III. Carbonaceous and Arenaceous Black Slate. | Taconic System. 1842-1846. Black Slate. | Animikie. | | | XIV-XVII at Marquette. XV and XVI at Menominee. | VI-XVI at Penokee. | Animikie Black Slates. Grand Portage. |
| GROUP IV. Hydromica and Magnesian Slate. | Taconic Slate. | | | | VI-XIV at Marquette. VI-XI at Menominee. | IV-VI at Penokee. | At "The Mission," Vermilion lake. Vermilion Iron Mines. |
| GROUP V. Quartzite and Marble. | Stockbridge Marble. Granular QuartzRock. | The Huronian of Canada. 1855. | | | V at Marquette. II-V at Menominee. | I-III at Penokee. | Ogishke-Muncie lake. |
| GROUP VI. Granite and Gneiss with Hornblendic Gneiss. | Primary. | Laurentian. | Laurentian. | Laurentian. | Laurentian. | Laurentian. | Laurentian. |

# PAPERS READ.

THE MISSOURI COTEAU AND ITS MORAINES. By Prof. J. E. TODD, Scientific Department of Tabor College, Tabor, Iowa.

THIS paper proposes to express briefly the results of the author's reconnoissance of the Coteau du Missouri under the auspices of U. S. Geological Survey. This reconnoissance consisted of a tour of nearly 2000 miles, so planned as to bring most of the Coteau, south of the Northern Pacific Railroad, under the eye. Some portions, however, remain yet without satisfactory exploration.

The common conception of the Coteau seems to be that it is a high plateau, for so it was called by the early voyagers, so it has been mapped, and so it appears from the glimpses, which one gets of it from the old routes along the James River. But a closer examination shows that it is not a typical plateau (not even as worthy of the name as its associate the Plateau du Coteau des Prairies). It is a mere skeleton of one, especially toward its southern end. Several valleys of considerable size like the "Great Ree Valley," which rivals the famous James River valley itself, cross it transversely.

If the term plateau be used less strictly, there seems to be no good topographical reason for separating the Coteau du Missouri from similar highlands west of the Missouri river, for the Missouri above Yankton flows in a comparatively insignificant valley, which is no more worthy to be considered a topographical boundary than are several of its western tributaries, but on the contrary perhaps less so. It is certainly insignificant when compared with the valley of the James which is 25–60 miles in width.

That the Missouri channel is an incidental and not a controlling feature in the region is further remarkably shown by its course above the mouth of the Niobrara. Although a large river, it flows 500 or 600 miles parallel with the edge of a great highland region, and 200–250 feet above the James valley bounding that region on the east, and strangely enough, although distant only 40–70 miles, with not only no rocky barrier to prevent, but transverse valleys to

encourage its passage, it has held its present track long enough to determine its permanent course, by the excavation of a channel. To show this more definitely, we may have recourse to railroad profiles which show the Missouri at Bismark 250 feet above the James at Jamestown, and at Pierre 200 feet above the James at Huron. While this is remarkable in a region where the strata are mostly soft clays arranged horizontally, yet the wonder is greater when we find evidence that the Missouri has recently run 300–400 feet higher than at present. We may find light upon this further on.

### 1. *The Structure of the Missouri Coteau.*

The Coteau is built mostly of Cretaceous clays of the St. Pierre group and capped with thin even layers of the Fox Hills sandstone northward, and with the Long River sandstone southward. The western side of the Coteau presents the usual features of deeply eroded topography. Buttes and flat-topped ridges abound. On its eastern side however, although there is evidence of a former similar character, it is now plastered over with drift and presents the usual features of stony morainic hills and basins. This plastering, as hinted before, does not present a smooth or continuous eastern front. In some cases it rises abruptly over 600 feet; in others, as along the railroads west from Jamestown, Aberdeen and Huron, the ascent is quite gradual, in fact imperceptible to an ordinary observer. The surface in the Ree Valley rises 5–8 feet per mile and is as even as an alluvial plain.

The Loup River sandstone has been traced with considerable confidence in the east front of the Wessington Hills and in the Bijous and with some doubt in bluffs along the Verdigris in Nebraska.

We have spoken of the strata as horizontal. There is some evidence of two low broad anticlinals, one extending northeast from the Bijou Hills and another also northeast from near the mouth of Grand River.

The bluffs along the left bank of the Missouri which constitute the western edge of the Coteau are over 400 feet high near Forts Rice and Yates, are 600 near the mouth of Grand river, 360 at Chamberlin, 700 at the Bijou Hills and 200 at the mouth of the Niobrara. The Coteau is bounded approximately on the east by the contour line of 1500 feet.

## 2. *The Moraines of the Missouri Coteau.*

There are two moraines quite easily traceable upon the Missouri Coteau. From their elevations, position and general features they are probably equivalent to the Altamont and Gary moraines. as named by Prof. T. C. Chamberlin, upon the Coteau des Prairies, This is not yet demonstrated however.

(1.) The outer moraine is the most pronounced, consisting of loops, convex usually toward the west and south, but in rare cases toward the northwest, as will be seen. These loops connect at reëntrant angles pointing toward the northeast and east, which are usually sharp and sometimes are extended into elongated ridges. The moraine varies in elevation with the region on which it rests. Its relative height is usually great at the head of the reëntrant angles or interlobular moraine. These frequently stand out like great promontories rising 150–400 feet above the plain around them. At the bottom of a loop the moraine is apt to be slight or wanting, if on lower land; the flow of water from the ice probably having carried away the debris as rapidly as it was pushed forward by the ice. On the other hand, in case the loop was pushed up an inclined plane and the water did not find free escape, it (the loop) is well developed all around. The outer moraine in some places is very rough and stony; at other points it is a smooth, broad ridge with few knobs, and covered with a deep fertile soil.

The course of the outer moraine may be described somewhat in detail, as follows:

A long narrow loop extends from near the east front of the Coteau down the valley, now partly occupied by Long Lake, nearly to the Missouri. From its sides it sends out smaller loops toward the south and west. The N. P. R. R. passes diagonally across the large loop crossing the moraine a little west of Sterling, about 20 miles east of Bismark. Thence after describing the extremity and southern side of the loop it turns N. E. to the vicinity of Crystal Springs, about 30 miles west of Jamestown, there it doubles upon itself forming a high abrupt ridge and returns S. W. about 15 miles nearly to the northwest corner of Logan county; thence it turns S. S. E. to the head waters of Beaver River, thence E. by S. about 20 miles in a series of small crowded loops nearly to the southeast corner of Logan Co., whence a long broken ridge of high morainic hills extends about 20 miles to the edge of the coteau in the northeast corner of the same county. After describing this

interlobular portion the moraine continues in its former direction (E. by S.) about 10 miles, then after forming a semicircular loop about 12 miles across it reaches a headland on the east edge of the coteau, about 30 miles west of a prominent bend in the James River, and 15 miles north of the 46th parallel. This portion of the moraine in Logan County is of indefinite breadth, the glacier having apparently shoved up against a close array of flat-topped ridges, between which the ice penetrated to some extent. Several deep narrow drainage channels were noted, but the debris of the glacier was carried away less than usual, and accumulated in a confusion of short broken ridges.

From the headland last mentioned the moraine extends 25 miles S. by W. in a direct line past the southeast corner of McIntosh county. Over this portion it coincides with the crest of a high ridge 12–15 miles in breadth and rising much of its course over 600 feet above the plain immediately east. It presents to an observer from that direction the nearest resemblance to the ideal Plateau du Coteau du Missouri, which is to be found anywhere south of the Northern Pacific. He ascends it with difficulty and travels an hour or more amid high stony knobs and circular basins before he gains a different view, but ere long he comes out on the western side of the ridge and overlooks a broad network of old channels and alkali lakes, scattered thick with boulders, but not showing typical glacial topography. The whole plain is 150–200 feet below him.

About six miles S.W. of the southeast corner of McIntosh county the moraine gradually circles around westward till its course is due west and perhaps a little north, while it passes 50 miles through the northern parts of McPherson and Campbell counties. This portion has not yet been clearly determined.

The moraine appears again following down the east bank of the Missouri river between it and the valley of the Bois Cachè creek, above the mouth of Grand River, where it is a high knobby ridge over 600 feet above the Missouri and nearly 400 feet above the plain just east. Thence it declines in elevation, as it passes down the west side of the Bois Cachè valley, and disappears. On the west side of the Missouri are ridges crossing the Moreau valley and circling around to the southeast, closely resembling the moraine from a distance. A closer study was impracticable. Whatever its course, it is found again, as prominently and characteristi-

cally formed as ever, crossing Swan Lake creek 10 miles east of its mouth and extending in a N. E. by S. W. direction with its inner side toward the northwest.

It keeps its N. E. course about 25 miles, nearly to the northeast corner of Walworth county, then describes a broad curve around to the E. and S. E. finally taking a S. by W. direction at a point about 30 miles east of the mouth of the Moreau river having enclosed a broad interlobular area including Swan Lake and its tributaries. This portion of the moraine is high and continuous but considerably worn by small water channels.

From a point 30 miles east of the mouth of the Little Cheyenne, the moraine begins to curve regularly and rapidly toward the east, a course it keeps for more than 20 miles, to the eastern end of what are locally called the Bald Mts. (near long. 99°, lat. 45°).

There doubling around westward in a distance of 5 or 6 miles it stretches away in a nearly direct line to the Missouri River a little south of Little Cheyenne, curving to the N. W. a little before reaching that point.

Thence along the east bank of the Missouri, 50 miles, to the vicinity of Pierre, are remains of reëntrant angles and interlobular moraines, some of them rising over 100 feet above the very even plain around them.

From the vicinity of Pierre the moraine turns N. E. forming an interlobular portion with a very conspicuous head, called East Medicine Hill about 200 feet above the plain.

Thence by a sharp curve S. W. then gradually around toward the east till it reaches another conspicuous headland called the Ree Hills.

From the northeast face of the Rees the moraine turns abruptly S. W. and loses itself in a bouldery plain.

Southeast of the Rees are two high morainic ridges extending in a N. E. by S. W. direction 5 or 6 miles in length and as far apart. They are evidently interlobular moraines, the corresponding loops being incomplete.

Still farther southeast, in a corresponding position, is a longer and less regular ridge, which extends N. E., upon a high swell known as the Wessington Hills, to the head of Sand Hill Creek. From the southern end of this ridge an incomplete loop connects with Turtle Point which stands upon the edge of the Coteau and rises over 400 feet above the plain east.

From Turtle Point the moraine extends high and sharp 12 miles S. then S. W. in quite a direct line to the east end of the Bijou Hills. Opposite Crow Lake and White Lake are gaps through which water formerly escaped N. W. The more notable variation from the direct course is a small semicircular loop of stony ridges pushed westward toward Red Lake.

In the vicinity of the Bijous the moraine is not prominent except at the east end of the East Bijou and along its southern side, where boulders are piled up to a height of 300 feet. The West Bijou though lower has no drift erratics upon its summit.

A stony ridge between Snake and Platte creeks, 100 feet high, about 10 miles S. E. of the Bijous, is clearly a portion of the moraine; but no more is found of it, until we come to the Cedar Creek Hills.

These form the point of a reëntrant angle toward the N. E. From this point there is a continuous range of hills, 100–300 feet in height above the plain N. E., to the mouth of Choteau Creek. Through this well defined range there are three prominent gaps or outlets, one occupied by Pease Creek, another, the grandest, partially by Lake Andes, another by Grass Lake.

Along the east side of Choteau Creek between it and Manuel Creek, is a high morainic ridge known as Choteau Creek Hills, 275 feet high. This is evidently an interlobular portion. But we have already followed the moraine beyond the Missouri Coteau, and to a point beyond which it disappears.

Eastward from near the mouth of the Niobrara, it evidently was either removed by the river as it formed, or else, crossing the river, remains buried in the deep loess deposits which cover that region. Future explorations will doubtless decide.

Recapitulating; we find, in this moraine, traces of four great lobes of the Ice Sheet pushing through from the James to the Missouri, viz., the Long Lake lobe, the Bois Caché lobe, the Ree lobe and the Pratt Creek lobe, as we may call them for lack of more descriptive names. They show surprising resemblances, the more prominent of which may be readily seen from the map.

Each, too, has its peculiarities. The Long Lake lobe has left its area abounding in sand, which is readily traced to the Fox Hills Sandstone in the vicinity. The Bois Caché especially toward its terminal end is much water-worn and presents sand hills, gravel plains and extensive fields covered with boulderets.

The subordinate lobe north of the Bald Mts., like the similarly situated one south of the Long Lake lobe, has left deeper basins, which are frequently long and winding and depressed 15 to 50 feet below the general level.

The Ree lobe on the contrary left its ground moraine very even, elevations and depressions varying more than 5 feet from the general level being rare over most of its surface. The same is true in less degree of the small lobes extending south from it. This lobe has also a curious fan-shaped termination as will be seen from the map.

The broad area south of the Wessington Hills is much of it even, although at several places, as near Grand View, it is broken into knobs and basins, having a difference of altitude of 30–50 feet. The even areas are some of them of lacustrine origin, and even where this is not evident the surface presents a curiously patched appearance, clayey spots of irregular shape lying about in the more prevalent black sandy loam, and *vice versa:* each soil being marked by its characteristic vegetation and showing different hygrostatic characters. This phenomenon may be compared with the sandy and clayey patches on a Missouri River sand bar.

(2) The inner moraine apparently crosses the Northern Pacific a little west of Crystal Springs. Thence it is believed (from the position of several peaks seen at a distance) to pass in a shallow curve S. E. to the headland in the northeast corner of Logan Co., about thirty miles southwest of Jamestown: thence it seems to lie along the edge of the Coteau in a direct line south-southeast to the headland in northwestern Dickey County: thence it is not easily separable from the outer moraine till the latter begins to curve more toward the west, when the former leaves it gradually, keeping farther south, but also curving westward.

It is unascertained whether it is traceable into the Bois Cachè valley or whether it takes a more direct course toward the highlands surrounding Swan Lake. Low morainic hills are found in position to favor either theory, but quite possibly the more remote are to be ascribed to a minor local fluctuation of the ice incident upon so slender a lobe. However that may be, it is well marked in a series of high morainic points forming a shallow curve approximately parallel with the outer moraine and 8 to 12 miles east of it, from the latitude of Swan Lake nearly to the eastern extremity of

the Bald Mountains. These it approaches more closely and forms a range of foot hills around them. After reaching their southern side it begins to swing away from them toward the south. Thence thirty miles or more have not been traced, but it was noted again west of Highmore curving across the Ree Valley from the northwest, a belt of knolly ridges fifteen to twenty feet high and three to four miles in width: thence it curves east and forms the foothill range around the higher Ree Hills. It has not been distinguished in the ridges southeast of the Rees, but knobs thirty to forty feet high south of Wessington on the Dakota Central, and a range of high stony hills along Sand Hill Creek, are probably the representatives of it. At Mitchell it is well developed again, especially in the Enemy Creek Hills a few miles south of the town. Thence it takes a southeast course and is lost in the rough plain of the James, southeast of Rockport.

At several places where this moraine approaches the outer moraine or is pushed up against the steep edge of the Coteau, its outer margin is fringed by a belt of lakes which are usually connected by ancient water channels. This has been noted in Western La Moure Co., in McPherson Co. and on the east side of the Ree Hills.

3. *The Portion of the Missouri Coteau outside the Moraines.*

There remains a portion of the Coteau not yet discussed, which we are now better prepared to study, viz., the portion outside the outer moraine.

We might perhaps expect to find it driftless, or at least covered with scattered boulders along the principal valleys only, the tablelands and buttes being driftless, but neither is found to be true.

This outer region divides itself naturally into three great divisions alternating with the four great lobes of the ice before sketched.

1. From the mouth of Grand River northward indefinitely, at least as far as Bismark, this region is covered with erratics from the northeast, except as they have been removed by later erosion, the caving of banks, and the cutting of channels.

The buttes opposite Fort Rice, 425 feet high above the river, show fifty feet of boulder clay upon their summits. The same seems generally true of the buttes and ridges over the whole re-

gion from the moraine to the Missouri River. How far west of the latter has not yet been determined with certainty. How to account for this deposit of drift is a problem not yet solved. A broad hint may be taken from the morainic deposits near the mouth of the Grand River. A comparison of altitudes shows that the summit of the moraine west of the Bois Cachè near the mouth of Grand River, is probably higher than any drift deposit over the whole of this area under consideration, except in the close vicinity of the moraine itself. If so, these drift deposits are probably *sub-aqueous till* as defined by Prof. Chamberlin, and were deposited in a lake produced by the damming of the Missouri by the Bois Cachè lobe. A demonstration of this theory remains to be worked out.

2. The region external to the moraine around Swan Lake and the Little Cheyenne. This area presents no buttes, but instead, hills of shales and laminated clay covered with a thin layer of drift, with a wonderful profusion of low sharp stony ridges on the sides and in the bottoms of the valleys, with their axes parallel with the lines of natural drainage. These are near the outer face of the moraine and were specially noticed west of Swan Lake and on the south side of the Little Cheyenne valley.

On the plain connecting Swan Lake with the Little Cheyenne are vast deposits of gravel. Apparently this area, surrounded, as it was, by ice on every side, was traversed by numerous streams of running water.

3. The area from Fort Pierre to the Bijou Hills presents features reminding us of the first area described, except that it has few buttes. Much of the region between the American and Crow Creeks is without drift but probably because it has been recently removed by erosion. South of the Ree Hills are extensive gravel deposits and a plain suggesting lacustrine action. About Chamberlin and Red Lake, the surface though resembling erosive topography is thickly covered with a boulder clay. Two explanations suggest themselves: either there was glacial action over an anciently eroded surface but too weak to smooth it; or the boulder clay is a floating-ice deposit, sub-aqueous till. The latter view is corroborated, by the absence of distinct moraines outside, and by the limitation of the boulders apparently to a water line, which was specially noticed near the West Bijou.

Looking farther we find some evidence that the ice crossed the

river near the mouth of Pratt Creek.[1] Moreover the height of the region about the Bijous and the configuration of the country was favorable for the formation of a barrier which would set back the water, away above Pierre.

A fourth area comes naturally next in order but it transcends our limits,—the Loess area which begins near the mouth of the Niobrara and extends indefinitely southward.

### 4. *Drainage of the Missouri Coteau.*

Before closing this paper it may be pardonable, considering their close relation to our subject, together with their intrinsic interest, to speak briefly: First, of the present drainage of the Coteau as related to the moraines, and second, with regard to the probable preglacial drainage as related to the same.

(1) The present streams of the Missouri Coteau are but the degenerate successors of the voluminous rivers of the Post-pliocene.

They may be divided quite naturally into three classes:

First, those outside of the outer moraine originating at the time of the occupation of the same by the ice.

Second, those between the two moraines, which were the principal channels of drainage for the ice when it stood against the inner moraine.

Third, those formed later within the inner moraine which mark the lower portions of the ground moraine after the recession of the Ice Sheet from the James Valley.

Of the third class we need say very little. Their existence and position are for the most part easily explained by the present configuration of the country. A little variation may be traced to the influence of the ice when it occupied the third or Redfield moraine, but this is not within the limits of the Coteau.

The second class is also comparatively unimportant on account of the nearness of the moraines to each other through most of their course. The Bois Cachè, Okobojo, Medicine, Pratt, and Choteau

[1] Since this paper was written, the writer has concluded, after a careful examination of the region, that the ice *did not pass* the present channel of the river at this point. No erratics were found on the west side, higher than 300 feet above the river, though the moraine at the Cedar Creek Hills rises over 600 feet above the same.

A significant feature, in the narrow valley of the river here, is a high terrace composed mainly of boulders, which commences at a height of 250 feet and slopes rapidly down to the river.

This indicates the former existence of violent rapids which conveyed the nascent moraine down stream, and probably checked somewhat the advance of the ice.

creeks are the most prominent examples of this class, and are all characterized by their deeply eroded valleys. Their principal sources all lie along the inner moraine.

The first class includes the most interesting streams of the region.

The Beaver River springs from a cluster of lakes grouped in and around a great gap at the extremity of the subordinate lobe just south of the Long Lake lobe; and with its branches probably drained about fifty miles of the moraine.

Swan Lake Creek and the Little Cheyenne, which were at that time united, drained a similar extent.

Crow and American Creeks had a similar position, the former is of unusual interest, as two of its principal branches lead us into the heart of the great interlobular moraines, the Rees, and the range of which Turtle Point is the head, *then* by *unmistakable channels through* them to the inner side of the moraine and *out upon the great ice sheet itself*. It produces strange sensations to pass up those dry flat-bottomed valleys with a steep bank on either hand 50 to 150 feet in height, almost built of boulders; huge cones of gravel evidently formed in ancient eddies here and there in the valley; similar valleys joining it now and then. You press on, wondering where the beginning can be, for your map tells you that there are streams which must cut right across its course if it continues, as far as you might judge from its width. You press on eagerly, you note the banks rapidly subsiding, but the channel you tread still preserves its gradual rise, then suddenly you come out upon the face of the range and a magnificent view of the plain 200 to 300 feet below, bursts upon you.

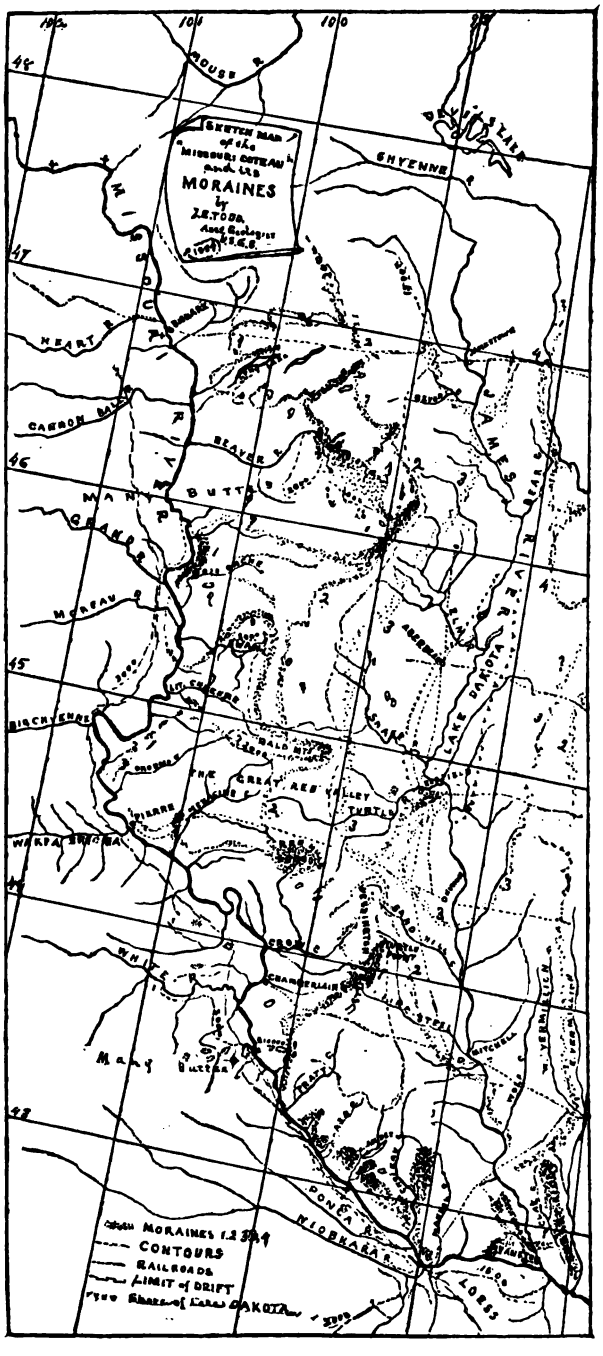
You look for the inclined plane which by easy steps has brought you to this altitude, and find it ending abruptly with the face of the hills. You realize as never before the mass of ice which once must have occupied the expanse before you. You can see that stream scores of yards in width leaving its icy banks, now vanished in thin air, for the stony ones which still remain.

(2) Preglacial drainage of the Coteau. Probably the most striking feature of the moraines, as we have traced them, is the curious breaking up of the ice sheet into finger-like lobes, and the turning of them so strangely toward the west. Why is this? We are not prepared to reply with confidence, but offer the following as a provisional explanation.

We have learned that the Ice Sheet was not so stubborn a body as was formerly supposed, but was turned by the configuration of the ground. This was specially true of its attenuated western edge.

A natural suggestion is, then, that the Long Lake valley, the Bois Cachè and Ree valleys were preglacial.

If so, what formed them? Looking across the Missouri we find a continuation of these valleys further west, where they are occupied by the Cannon Ball, the Grand joined with the Moreau, and the Big Cheyenne with the Wakpa Shicha; while the White River is related somewhat similarly to the lobe south of the Wessingtons. May we not then eventually find evidence that these rivers once flowed thróugh to the James valley,— that great valley which seems more deserving of some stream like the Missouri? That very stream perhaps once occupied it, before being forced by the ice sheets to leave it, collect its tributaries, and escape to the south by its present course. We are not prepared however, to say that this was probably the case, for not only the general direction of these transverse valleys but also the relation of the James valley to that of the Red River, indicates that the drainage of the whole region was formerly toward the northeast. The Upper Missouri may have been only one of several similar tributaries of the Red River. Whatever may eventually be shown to be true, we seem to have found in the glaciation of the Missouri Coteau an explanation of the surprising course of the Missouri River, which we noticed at the outset.


SKETCH MAP of the "MISSOURI COTEAU and its MORAINES by J.E. TODD, Asst. Geologist U.S.G.S.
MORAINES
CONTOURS
RAILROADS
LIMIT of DRIFT
LOESS
103°
102°
101°
100°
99°
48°
47°
46°
45°
44°
43°
42°
MOUSE R.
DEVIL'S LAKE
CHEYENNE R.
HEART R.
CANNON BALL R.
BEAVER R.
JAMES RIVER
MISSOURI R.
BUTTE
MORAU R.
BIG CHEYENNE
GREAT BEND
WHITE R.
MAY
BUTTE
PONCA
NIOBRARA R.
LAKE DAKOTA
DAKOTA

A STUDY OF ONE POINT IN THE ARCHÆAN-PALÆOZOIC CONTACT LINE IN SOUTH-EASTERN PENNSYLVANIA. By PERSIFOR FRAZER. Docteur ès-Sciences Naturelles (Université de France), Philadelphia, Pa.

[ABSTRACT.]

THE crystalline rocks in and near Philadelphia were classified by Rogers into three belts of which he thought that two, the northerly and the southerly, might be the same; and the middle, above them. He never doubted that the Chester Valley limestone was far above all these gneisses and mica schists, and the hydro-mica-schists which formed his Upper Primal series.

Since then disputes having arisen in various parts of the world as to the stratigraphical relationships of certain belts of crystalline rocks near the contact line of palæozoic and archæan, Philadelphia was not wanting in defenders of the theory that the schists and gneisses, forming its foundations, were laid down on the limestone known formerly as No. 2, or the Auroral, which is universally ascribed to the Lower Silurian Age.

These suppositions have often been vaguely heard as corollaries to the statements of orders of superposition in other parts of the United States, and of the world; but have been presented tangibly, so far as the writer knows, by Mr. Charles E. Hall, in one publication only, viz., "$C_6$" of the volumes of the 2nd Geological Survey of Pennsylvania. Without at this time sketching the full data or bearings of Mr. Hall's views it may be said that he deemed the proof of his theory of structure to be more fully illustrated at that portion of the course of the Schuylkill near Conshohocken than at any other point. This, as he remarked, was the key to the whole structure of the southern Chester Valley; and this implied that if the superposition of the limestone could be clearly shown here, there was no other place where it would present equally serious difficulties. The reason of this is plain. This region exhibits a sharp folded outcrop; so sharp indeed that it would seem that but one hypothesis of structure could successfully account for the four alternations of schist and limestone on a short section line.

Mr. Charles E. Hall's views of this structure as published in the just cited volume $C_6$ of the Second Geological Survey of Pennsylvania, are found on p. 32; where also a small section from Henderson's Station to Mechanicsville gives graphic form to his hypothesis.

Section Line from Quincy near Merion Furnace to Bridgeport.

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This led the writer to put together, into the form of an ideal section, some notes that had been made several years previously, but never plotted; and to add this to a pamphlet on "the horizon of the South Valley Hill rocks." It appears there, that the portions of the measures which Mr. Hall had made *anticlinal*, seemed to construct themselves on the writer's section as *synclinal* and vice versa. This result was so unexpected that a later study was made of the same region, and from entirely independent data. The result of this coincides in all essential particulars with the structure as indicated in the section just spoken of, and is therefore a corroboration of it. See accompanying Section A—B.

The new section begins at South Bridgeport with a dip in Potsdam sandstone of ± S. E. ± 10° and following closely in a southeasterly direction, a limestone dips unconformably against it. For an interval of a mile no exposures were observed; after which a series of gentle rolls in the limestone are noticed, affecting a thickness of at least 600 ft., to a point about midway between Gulf Mills and Henderson's Station, where there is a sudden descent of the limestone in an almost vertical direction, followed by a rise and a series of complex compressed folds which would not be apparent from stratigraphical, but which are made evident from lithological evidence. There appear to be three and a half anticlinals involved in the production of this structure up to the point where, in West Conshohocken, a trap dyke seems to mark the line of a fault and slip of unknown depth. The latter, however, is probably not very profound since a shorter and more plicated structure appears to the northeast between the line of this trap and the clays which mark the decomposed crystalline rocks on the northwest slope of the Laurentian "Buck Ridge."

The phenomena thus seem to suggest:

(1) An unconformable contact of limestone on the Potsdam and not a conformable contact as suggested by Mr. Hall in his section on p. 32 of $C_6$.

(2) A series of gentle folds.[1] Mr. Hall, on the contrary, in the section above alluded to, suggests a monoclinal of limestone followed by a series of Trenton slates and dipping southeast.

(3) A tightly folded series of anticlinals of hydro-mica schist (not a simple synclinal as represented in Mr. Hall's section) over-

[1] The writer has suggested two synclinals with the crest of an anticlinal separating them; but further and fuller development may modify this in unimportant particulars.

lain from place to place, wherever the crystalline rocks sank below the present level, by equally compressed synclinals of limestone.

(4) There is a break at the trap dyke of West Conshohocken, disturbing the measures, to an extent not entirely known. Finally there follows a series of tightly folded plications, in which the hydro-mica-schist seems, as a mass, to be always *below* the limestone: and finally the unconformable contact with the clays of the Buck Ridge.

The conclusion that the writer draws from this small area is also strictly conformable to the conclusions he has drawn from his study of the contact line of limestone and schist from Tredyffrin townships to Quarryville, and in fact along the entire border line of schist and limestone in Chester, Lancaster, York, Cumberland and Franklin Counties, Pennsylvania.

So far as the Chester Valley is concerned it adds additional ground for believing the theory established by the writer in his Thesis presented to the University of France in 1882; *i. e.*, that the Chester Valley represents the northern half of a synclinal of which the southern half has been cut off and thrown up on the south, bringing the pre-Cambrian schists in contact with the limestone.

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IDENTIFICATION OF THE GREEN MOUNTAIN GNEISSES IN EASTERN NEW ENGLAND. By Prof. C. H. HITCHCOCK, Dartmouth College, Hanover, N. H.

[ABSTRACT.]

THE subject was illustrated by a large diagram not reproduced in this volume, which delineates in detail the positions of the various crystalline groups upon thirteen parallel lines between Massachusetts and Canada, extending usually from Maine to New York across the two states of Vermont and New Hampshire.

1. The typical area of the Green Mountain gneiss is that of the main range of the elevated district. The rock is visible upon every one of the sections, and appears to exhibit an anticlinal structure. The first suggestion of this structure was provisionally made by C. B. Adams in 1846, substantiated in the final report of Vermont 1861, and finally admitted by J. D. Dana in 1882 for the southern part of the state.

2. This gneiss is identified in southern Vermont, New Hampshire and Massachusetts by its repetition in anticlinal folds. As

it reappears it possesses essentially the same lithological characters; but a similarity is not regarded as identification unless indicated by exact mineralogical features. We oppose the doctrine that a gneiss may be replaced by a synchronous mica schist, syenite, hornblende schist, or any other unlike rock.

3. The following are the areas supposed to be identical with the Green Mountain gneiss: (1) between Halifax and Hartland, Vt., (2) between Winchester and Milan, N. H., running nearly the whole length of the state, (3) in the Contocook valley and to the north in Warner, (4) between Jaffrey and Weare, N. H., (5) between Temple and Hopkinton, N. H., (6) the very important area occupying the basin of Lake Winnipiseogee, which may be a repetition of (3) to (5), (7) a highly crystalline range from the Massachusetts line at Mason to Barrington. This is the northward continuation of part of the Worcester Co. gneiss in Massachusetts. (8) from Nashua to Fremont, N. H. This is the Chelmsford and Bolton range of Massachusetts.

4. It is supposed that this gneiss is of Laurentian age. Our division of that system is threefold: first, at the base, the various areas of porphyritic gneiss, supposed to be allied to the Ottawa, Laurentian of Logan; second, our Green Mountain gneisses as detailed above; third, the Montalban or Upper Laurentian. As shown in my New Hampshire Report the Montalban underlies the Huronian.

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THE HORIZONS OF PETROLEUM AND INFLAMMABLE GAS IN OHIO. By Prof. EDWARD ORTON, Columbus, Ohio.

[ABSTRACT.]

PETROLEUM and carburetted hydrogen gas are widely distributed in stratified rocks. All rocks of the Ohio scale are likely to show the presence of one or both, when penetrated under deep cover. The supplies of economic value have thus far been found in Devonian, Sub-Carboniferous and Carboniferous series of the state. The Devonian rocks yield a small amount of low-pressure gas. The coal measures yield small quantities, at several horizons, of both gas and oil, but the main supplies in Ohio are derived from the Sub-Carboniferous series. The boundaries of this series are still in dispute, but the general order of its elements is well settled. Two of these elements, and two only, have interest as repositories of

petroleum and gas, viz., the Logan Group and the Berea Grit, the former having a thickness of 150 to 200 feet and the latter ranging from 5 to 50 feet.

In situation and general geological relations, both of these strata conform to the requirements of "oil sands" as now understood. An "oil sand" is a sandstone or conglomerate immersed in shale.

The Berea Grit has beneath it the great series of shales, viz., the Bedford–Cleveland–Erie–Huron Shales which stretch below in inseparable beds for 1800 feet, at least in the centre of the coal basin. It is covered by the Berea Shale 20–50 feet thick and the Cuyahoga Shale, 250 to 500 feet thick. This same stratum, the Cuyahoga Shale, makes the floor of the Logan Group. The Logan Group is largely conglomeritic, and what is thus designated often overpasses the sub-carboniferous boundary, no doubt, taking in the Sharon conglomerate as well. The roof shales are accordingly of different series in different instances. The upper group is the main salt horizon of Ohio, the wells of the Muskingum, the Hocking and Ohio Valleys all being derived from this source. The Berea Grit is the main source of high pressure gas and of what oil, Ohio now yields. It also supplies brine to the Tuscarawas salt works.

Recent records obtained from the very numerous drillings that are going down in many sections of the state show conclusively that the Berea Grit, often reduced to 5 or 10 ft. in thickness, is the source of these tremendous flows of gas that light up the country for miles, etc.

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THE CORRELATION OF THE LOWER COAL MEASURES OF OHIO AND EASTERN KENTUCKY. By Prof. EDWARD ORTON, Columbus, Ohio.

[ABSTRACT.]

A REMARKABLE symmetry has been seen to characterize the northern portion of the great Appalachian coal field by all who have studied it. The more full and accurate our knowledge becomes, the more clearly is it seen that the system grew in a very orderly manner. A number of the main coal seams, for example, can be traced by bodily continuations for scores and even hundreds of miles along the ancient margins of the seas by which they grew. The character of the coal may change and the seam may show by its expansions and contractions the varying

changes of fortune it underwent, but the swamp holds on with unmistakable identity.

The composition of the coal measures has been worked out much more fully and minutely in Western Pennsylvania than elsewhere and a general order has been established that must be considered final. The Lower Coal measures are found to contain a dozen seams all of which have minable thickness in some portion of their extent.

These seams can be followed into Ohio and across Ohio. Three principal subdivisions in particular are conspicuous and easily traced, viz., the Mercer Group, the Kittanning Group and the Freeport Group of coals and associated elements.

It is evident that the coal field of Eastern Kentucky is part and parcel of the same field that we follow from Pennsylvania across Ohio, and yet there has been as little recognized community of structure, aside from one or two elements, as if the fields had grown with separate histories.

But the moment that the sections are followed across the valley, the identity comes to light. Prof. A. R. Crandall is our authority for Eastern Kentucky. Uniting with him in an examination of type sections in both fields, it becomes obvious that one set of names will suffice for all the elements. Some drop out temporarily but the sections are maintained.

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THE SALT WELL AT HUMBOLDT, MINNESOTA. By Prof. N. H. WINCHELL, Minneapolis, Minn.

[ABSTRACT.]

THE author gave a description of the section of the rocks passed through by the drill, which penetrates to the depth of 592 feet. The salt water rises from the bottom of the drift sheet, as well as from below a limestone 291 feet thick. It was thought to be from a great basin of brine which underlies the drift sheet, which consists wholly or nearly so of impervious clay, and hence permeates any rock-horizon which happens to compose the immediate surface throughout a wide extent of territory, reaching from the valley of the Saskatchewan southward into Dakota and Minnesota. The strength of the brine was stated to be about one-third that of the Syracuse wells.

Although formerly the brines of the northwest have been referred to the Cretaceous and to the Devonian rocks, the author thinks there is evidence of the existence of Carboniferous rocks in the country southwest of the Saskatchewan, parallel to those that bear brine in the state of Michigan, and that it is very probable that this brine may become as valuable to the northwest as the brines of the Carboniferous have to the state of Michigan.

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A REVIEW OF THE GEOLOGY OF DELAWARE. RESULTS OF A SURVEY NOW IN PROGRESS. By FREDERICK D. CHESTER, Prof. of Geology, Delaware State College, Newark, Delaware.

[ABSTRACT.]

REFERENCE is made to the early report of Professor James C. Booth (1841) and its deficiencies briefly discussed. The formations represented within the state are Metamorphic and Eruptive rocks of doubtful age, Cretaceous, Tertiary and Quartenary. An eruptive mass, a continuation of the syenitic areas of southeastern Pennsylvania, covers a club-shaped area lying just north of the P. W. & B. R. R., and consists of syenitic gneisses with associated Gabbros and Hyperites. The dip of these rocks is to the northwest, upon the flanks of which rest a series of micaceous gneisses and schists with which are associated seams of hornblende schist, vitreous quartz and dikes of orthoclastic granite. The mica schists and gneisses overlie a coarse magnesian marble, which itself is underlaid by a quartzitic rock of possibly Potsdam age. The probable order of the crystalline rocks becomes then — Quartzite, Magnesian Marble, and Mica Schists. The question of the Palæozoic age of the mica schists is here briefly discussed.

Lying upon the upturned edges of the eruptive rocks are a series of strata of Cretaceous age dipping at an angle of 26′ to the southeast. The width of the Cretaceous belt is eighteen miles. The subdivisions very nearly correspond to those of New Jersey. They are Plastic Clays, Sand Marl, Lower Marl Bed, Indurated Marl Bed and Middle Marl Bed.

At Noxontown Mill pond the uppermost layer of the Middle Marl Bed is seen to dip beneath a ten foot stratum of *blue clay* in which have been found fossils of Miocene (?) age; near the latitude of Murderkill Creek the Miocene is succeeded by three feet of clay

beneath which is a stratum of *glass sand*. No fossils have been found in either bed in sufficient quantity to determine the question of age; but the *glass sand* is most probably the exact equivalent of the glass sand of New Jersey, which according to Prof. Cook is Pliocene. The upper clay is therefore of later Pliocene age or early Quatenary. Modern shells found at the junction of this clay and the overlying gravels would render this highly probable or even certain. Overlying nearly all the preceding formations and reaching 200 feet up the flanks of the Azoic hills is a uniform layer of gravel, which for the northern half of the state is identical with the *red gravel* of the Delaware river valley and which to the south merges into a white estuary sand. The tops of some of the highest hills are furthermore capped by isolated patches of the ancient Bryn Mawr gravel of Prof. H. C. Lewis.

The shore of the river and bay is also edged by a belt of black *bog clay* of recent origin.

| | | | |
|---|---|---|---|
| Post-Pliocene or Quatenary. | | Modern<br>Post-Glacial<br>Glacial | Bog Clay.<br>Delaware Gravel and Estuary Sands. |
| Tertiary. | | Pliocene | Blue Clay<br>Glass Sand |
| | | Miocene | Blue Clay. |
| | | Eocene | |
| Cretaceous. | Upper Cretaceous. (Chalk.) | Middle Marl Bed. | Yellow Sand<br>Shell Layer.<br>Pure Green Sand. |
| | | Indurated Marl Bed. | Indurated Marl.<br>Red Sand. |
| | | Lower Marl Bed. | Argillo-Micaceous Marl.<br>Shell Layer.<br>Cretoidal Marl. |
| | Middle Cretaceous. (Upper Green Sand and Gault.) | Sand Marl. | Sand and Clay Marls. |
| | Lower Cretaceous. (Wealden?) | Plastic Clays. | Red Clay.<br>Fire Clays, Potters' Clays and Sands. |
| Metamorphic and Eruptive Rocks. | | Age Doubtful. | Granite Gneiss and Mica Schist.<br>With Eruptive Gabbros.<br>Magnesian Marbles.<br>Quartzite. |

THE GEOLOGICAL AGE, CHARACTER AND ORIGIN OF GYPSUM BEDS OF CAYUGA Co., NEW YORK. By S. G. WILLIAMS, Professor of Geology, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE purpose of this paper is to show by fossil evidence that these, the richest gypsum deposits of N. Y., belong to the Lower Helderberg period and not to the Salina; that they are continuous beds and not isolated masses, as elsewhere east and west of Cayuga Co.; and that they probably owe their origin to a transformation of limestones by the action of acidulated water derived from sulphur springs.

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A GREAT TRAP DYKE ACROSS SOUTHEASTERN PENNSYLVANIA. By Prof. H. CARVILL LEWIS, Germantown, Pa.

[ABSTRACT.]

IN his Geology of Pennsylvania, Prof. H. D. Rogers described a narrow trap dyke six miles in length which crossed the Schuylkill river at Conshohocken, ten miles northwest of Philadelphia. In Report $C^6$ of the Second Geological Survey, Mr. C. E. Hall has described and mapped this dyke as having a length of something over eight miles. In the present paper the author gives the result of his personal observations in tracing this dyke continuously across southeastern Pennsylvania, from the Maryland line to within ten miles of the Delaware river in Bucks County, which dyke, taken together with some parallel dykes of similar constitution and age in Bucks County forms a series of nearly continuous dykes, upwards of ninety miles in length, and becomes an important feature in the geology of the state.

Beginning with a prominent outcrop near Doylestown, the author traced the dyke continuously through Bucks, Montgomery, Delaware and Chester Counties, and proved by a detailed map and description of its outcrops at each stream and road crossing, that, although so narrow and so much decomposed as to be visible generally only in the form of a long line of boulders, rounded by concentric weathering, it nevertheless was practically continuous

for more than seventy miles. The small "jogs" in the course of this long, narrow dyke, which occasionally displaced portions of it for short distances, were regarded as due to contemporaneous faulting.

South of Doylestown the dyke abutted against the southern side of a great fault of several thousand feet upthrow which threw up the whole thickness of the Trias, bringing its floor of Palæozoic strata to the surface. For a distance of nearly twenty miles, this important fault had been followed and mapped by the author who had found the line to be marked by a peculiar "fault rock," composed of broken fragments covered by "slickensides." The strata on one side of the fault often dipped at right angles to those on the other side. A long trap dyke of precisely similar composition, as shown by microscopic examination, abutted against the northern side of the great fault at a distance laterally of five miles from the end of the long dyke just described, and the question was discussed whether or not it could be considered as the same dyke, laterally displaced, or whether the eruption of trap and the faulting were contemporaneous.

The trap dyke was shown by both chemical and microscopical examination to be of identical composition throughout the whole of its course, being a typical Triassic diabase (dolerite) composed of lath-shaped plagioclases enclosing augite and magnetite. It is distinct from other eruptive masses near it, and passes successively through Laurentian, Cambrian, Silurian and Triassic formations. While marking the place of a great crack in the earth's crust, which, running about northeast and southwest, is approximately parallel to the flexures of the Appalachians, there was no evidence that the dyke occupied a fault.

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## Evidences of local glaciers in the Catskill Mountain region.

By Prof. John C. Smock, State Museum, Albany, N. Y.

[abstract.]

1 Reference to paper on upper limits of the continental glacier in the Catskills.

2. General trend of groovings and striations.

3. Material of the glacial drift and its probable sources.

4. Topography of the region with reference to its glaciation.

5. Descriptions of a few typical moraines:

(*a*) Schoharie Creek Valley at Red Falls, Greene Co.

(*b*) Schoharie Creek Valley near Gilboa, Schoharie Co.

(*c*) Stony Clove near Chichester, Ulster Co.

(*d*) East branch of the Delaware at Margaretville in Delaware County.

6. Modified drift of the valleys.

7. Conclusions as to close of the glacial period in this region.

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AN ATTEMPT TO DETERMINE THE AMOUNT OF CHEMICAL EROSION TAKING PLACE IN THE LIMESTONE (CALCIFEROUS TO TRENTON) VALLEY OF CENTRE CO., PA., AND HENCE APPLICABLE TO SIMILAR REGIONS THROUGHOUT THE APPALACHIAN SYSTEM. By Prof. A. L. ERVING, State College, Pennsylvania.

[ABSTRACT.]

THE method pursued is as follows: the amount of water flowing from a given hydrographic basin, in the region in question, is determined from the cross section and velocity of the stream draining it. The amount of solids in the water is determined by evaporating specimens of it. These data together with the area of the basin form the basis of calculation. The region selected is that of the Spring Creek basin which forms a considerable portion of the limestone valley of Centre Co. The measurements were made just above the old dam below Bellefonte and below all visible tributaries. The following results were obtained: width of stream 22.86 metres (75 ft.), depth of stream, average of six measurements .823 m. (2.7 ft.) giving as the cross section 18.81 m.$^2$ (202.5 sq. ft.).

The velocity was determined by floating surface particles and a long bottle weighted so as to float at different depths. An average of six tests showed the velocity to be 994.776 m. per hour.

The above determinations give 18,712 m.$^3$ as the amount of water removed per hour. The water shows on evaporation (average of two tests) 155.3 grams per m.$^3$ This gives as the amount of solids removed per hour 2,905,974 grams or 25,456,560 kilos per annum.

The area of the region in question is 100 sq. miles hence 254,566 kilos is the amount of solids removed per annum per sq. mile, approximately 281 tons.

A portion of the water of Spring Creek, however, falls upon the bordering mountains, probably one-fourth of the whole. This water shows on evaporation 16.5 grams per m.$^3$ or about one-tenth of the amount in Spring Creek water, hence probably one-fortieth of the solids in Spring Creek comes from the mountains. Making this deduction we have, as the amount per sq. mile per annum, 190,925 kilos or 275 tons.

Assuming the sp. gr. of the solids to be 2.8 we have as the mass removed per sq. mile per annum, 91.3 m.$^3$ This spread over the surface of one sq. mile would form a coating $\frac{1}{29173}$ m. in thickness, hence it would take 29,173 years to lower the valley one m. by chemical erosion, or about 9000 years to remove 1 ft. from the entire surface.

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NOTICE OF AN IMPORTANT WORK ON THE ORIGIN OF THE CRYSTALLINE SCHISTS, BY DR. J. LEHMANN, PROFESSOR OF GEOLOGY AT BRESLAU, ILLUSTRATED BY AN ATLAS OF 28 PHOTOGRAPHIC PLATES. 4°, BONN, 1884.[1] By GEO. H. WILLIAMS, Johns Hopkins University, Baltimore, Md.

[ABSTRACT.]

THE author gives very important conclusions relating to the origin of certain crystalline schistose rocks based upon nine years continuous study of the Saxon granulite area and other similar regions in central Europe. Naumann regarded the granulite as an eruptive rock which had metamorphosed surrounding sediments by contact. The more recent Saxon geologists regard it as a metamorphosed sediment on account of its distinct bedding. Lehmann returns to Naumann's idea of its eruptive nature, adding that its present form, as well as that of the surrounding schist, was produced by the forces which elevated the mountains of that district. The key note of the whole work is the effects of the orographic forces in metamorphosing rock masses. These effect changes in the *mineralogical constitution* and in the *structure*. The former is accomplished by the development of new minerals, similar to those produced in the well-known metamorphism of contact zones near

[1] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine mit besonderer Bezugnahme auf das Sächsische Granulitgebirge, Erzgebirge, Fichtelgebirge und Bairisch-böhmische Grenzgebirge, von Dr. J. Lehmann.

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[illegible] localities at Narragansett
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[illegible] here (to date), a list of 74
[illegible] follows:

Virginia, 6.
North Carolina, 16.
South Carolina, 1.
Michigan, 7.
Wisconsin, 2.
Nevada, 1.

produce a schistose or banded structure in eruptive masses. Lehmann does not allow a true viscosity, but a plasticity, like that of wet clay, due to a sliding of the smallest particles upon each other. (Cap. XVI.) The observations made upon this fine crushing and consequent movement, producing "pseudo-eruptive" structure, are very interesting.

Another point of much importance relates to the formation and subsequent metamorphism of rocks neither altogether eruptive nor sedimentary. Such are produced by the cementation of schist breccia fragments by eruptive matter or the impregnation of more or less fissured and contorted schists by molten magma. In this manner the curious structure of the Phyllite gneiss of Bavaria (Cap. VII), as well as of the gneiss mica schists, biotite gneiss and cordierite gneiss of the granulite area (Cap. X and XI) are explained. The more or less complete assimilation of schist fragments may materially alter the character of an eruptive rock. An apparent bedding may even be produced by regularly arranged schist inclusions.

The granites, which are regarded as having been intruded into the granulite area after its fissuring and elevation were complete, are treated at considerable length. Some coarse pegmatitic veins are thought to be of eruptive origin, others to have been formed by granitic secretions emitted from the magma at the time of its cooling. This granitic material has impregnated many schists about the exterior of the area.

The atlas of photographic illustrations, 159 in number, is so good as almost to supply the place of the original specimens, studied and described. They are executed with the greatest pains and in the best style and cannot be spoken of with too high praise.

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ON A SECTION OF THE STRATA OF THE CRETACEOUS AND TERTIARY FORMATIONS OF ALABAMA. By Prof. EUGENE A. SMITH, University of Alabama, Tuscaloosa, Ala., and LAWRENCE C. JOHNSON, Washington, D. C.

[ABSTRACT.]

IN this paper it was shown that 500 feet of strata lie beneath the lowest of the Cretaceous beds heretofore described: the geological

positions of the phosphatic deposits were pointed out. The relation between the Claiborne and some underlying beds were pointed out, and the nature and thickness of the beds which underlie the Buhrstone of Prof. Tuomey were made known.

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MUSICAL SAND, ITS WIDE DISTRIBUTION AND PROPERTIES. By Prof. H. CARRINGTON BOLTON, Trinity College, Hartford, Conn., and Dr. ALEXIS A. JULIEN, Columbia College, New York.

[ABSTRACT.]

AT the Minneapolis meeting of this Association we gave some account of the so-called "singing beach" at Manchester-by-the-Sea, Mass., and of the occurrence of sonorous sand at Eigg and other foreign localities. During the twelve months which have elapsed since our joint paper we have not ceased to pursue our investigations, and although these are by no means completed we here present a summary of the more important results.

By means of extensive correspondence we have established the fact that sonorous sand instead of being a rarity is of very common occurrence and widely distributed. Through the courtesy of Mr. Sumner I. Kimball, General Superintendent of the U. S. Life Saving Service, circulars were sent to all the keepers of life-saving stations throughout the United States, making inquiries as to the occurrence of sonorous sand, and soliciting samples. Replies have been received from about 85 keepers, 65 of whom report affirmatively in letters of much interest. It is of course impossible to enumerate them in this abstract, much less quote them. One of us also has personally visited localities at Narragansett Pier; near Norfolk, Va.; on Lake Champlain, near Plattsburg, and both of us have studied the properties of the sand at Far Rockaway, Long Island. We have therefore (to date), a list of 74 localities in America distributed as follows:

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|---|---|
| Maine, 3. | Virginia, 6. |
| Massachusetts, 4. | North Carolina, 16. |
| New Hampshire, 1. | South Carolina, 1. |
| Rhode Island, 4. | Michigan, 7. |
| New York, 12. | Wisconsin, 2. |
| New Jersey, 17. | Nevada, 1. |

The number is constantly increasing as the reports from keepers of life-saving stations arrive.

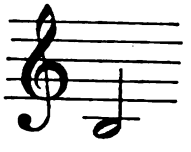
To Professor S. F. Baird we are under obligations for valuable aid in obtaining information and samples from foreign localities. Through the Smithsonian Institution we have secured specimens of sonorous sand from the Island of Bornholm, Denmark; Colberg, Prussia; and Kauai, Hawaii Islands. Our list of foreign localities now numbers 18, thus making a total of 92. Moreover we have collected through the agencies named and through private hands, over 320 samples of sonorous and non-sonorous sand, the microscopical study of which has occupied one of us for many weeks and the results of which will form a special paper to be presented in connection with this one.

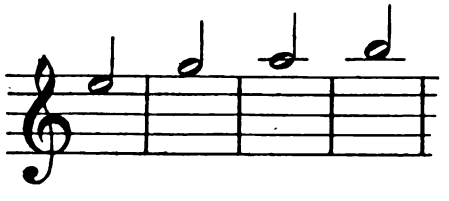
In July and in August of this year, experiments have been conducted both at Manchester-by-the-Sea and at Far Rockaway to determine accurately the properties of the sonorous sand with the object of explaining the cause of its singular characteristics. The results of these experiments are in part as follows.

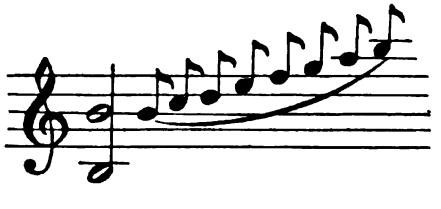
The loudest sound of which a given sand is capable is most conveniently produced by confining a quart or more in a bag and strongly striking together the contents. Sounds thus produced were heard distinctly at both the Manchester and Rockaway beaches at a distance of 150 to 200 feet, the distance varying according to the strength and direction of the wind and the interference of the surf noise. At Rockaway a careful experiment was made in fields removed from the beach. The sound produced by striking the bag was heard at a distance of 450 feet measured carefully by a tape line. The sound has a hoot-like quality easily recognized. The experiment was made by four persons, in two pairs, each of which had bags of sand; moreover the experiment was made just at dark so the operators could not be seen by the hearers. A light breeze favored those who heard the sound at 450 feet; the sound was however heard 400 feet against the wind.

[The character and intensity of the sounds obtained by friction were experimentally shown to the audience.]

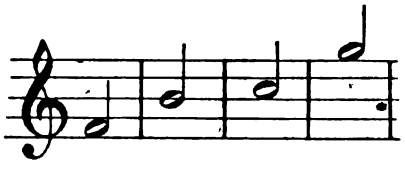
The character of the sounds obtained by friction on the beach is decidedly musical and we have been able to indicate the exact notes on a musical staff. The shrillness and lowness of note depend chiefly on the quantity of sand disturbed; by plunging both

hands into the sand and bringing them together quickly with a swoop a large quantity of the sand vibrates and we hear a tone of which the dominant note is

By stroking the sand nearer the surface and with less force very high notes are heard somewhat confused. The following were heard at different times.



By rubbing firmly and briskly a double handful of the sand several notes on a rising scale are heard, the notes rising as the quantity of sand between the hands diminishes. We do not hear each note of the scale separately, but the ear receives an impression something like that formed by sliding a finger up a violin string at the same time that the bow is drawn.

The range is very remarkable and decided.

These results were obtained at Manchester; the Rockaway beach gave somewhat different tones; the B below the ledger line

was not heard at all, but the following notes were heard at different times according to the manner of the friction.

In both cases the notes were determined by comparison with those made on a violin at concert pitch.

The evanescent character of the acoustic quality of the sand is very marked. Sand which has been recently wet requires thorough drying and insolation (?) before it again resumes its acoustic power. Consequently sandy beaches do not always possess the sonorous power in equal measure, and the seeker sometimes fails to discover musical sand in the locality reported. Meteorological conditions, the dryness or moisture of the atmosphere decidedly affect the sonorousness.

Musical sand is easily deprived of its acoustic properties in several ways. Wetting it is effectual of course, but long continued friction between the dry hands also accomplishes the result. The quickest way of "killing" the sand (except by water) is to shake a small quantity in a glass bottle, or better in a tin box. When first agitated in a tin box a peculiar sound is heard which entirely ceases after 20 to 25 slow up and down movements of the box.

Under what circumstances and for how long a period of time sonorous sand will preserve its quality is a question which at this writing we cannot definitely answer. The results obtained are very conflicting, but we believe that the sand preserves its powers best when hermetically sealed in bottles. When collected in bags it sometimes loses the power in a few hours.

Attempts to restore to "killed" sand (that is sand rendered mute by any of the above named methods) its sonorous properties have met with indifferent success; experiments are in progress to accomplish this object.

Experiments made on the beach at Far Rockaway with a gold leaf electroscope gave no evidence that electricity is concerned in

the acoustic phenomenon. The instrument was proved to be sensitive but behaved alike with both sonorous and mute sand. For the use of this instrument we are under obligations to Dr. Arthur H. Elliott, who also aided in the experiments.

Sonorous and mute sand occur on the beach closely adjoining but they cannot be distinguished by the eye; friction alone determines the difference. In sand of strongly marked acoustic properties a tingling sensation is perceived in the fingers and also in the toes even through boots.

Careful search in literature shows that allusions to sonorous sand are scattered sparingly through writings of a thousand years. An obscure allusion to the phenomenon occurs in one of the singular tales forming the collection known as the Arabian Nights Entertainments. Old Chinese chronicles mention sonorous sand occurring in the desert of Lob-Nor, Marco Polo narrates superstitions concerning it, the Emperor Baber refers to a locality in Afghanistan, and many travellers in the East describe hills of moving sand whence issue mysterious noises. The famous *Jebel Nakous* briefly named in our previous paper situated on the east of the Gulf of Suez has been visited by at least six European and American travellers. By comparing their several descriptions we have discovered that they describe not one locality, but two, or possibly three, in the same region. Photographs of two of these localities are herewith exhibited, the first being taken from a view by Lieut. Wellstedt, R. N. and the second from a rough sketch by Prof. H. A. Ward of Rochester. Details of the phenomena reported cannot be given in this abstract; it suffices to say that the dry sand rests on a steep incline and when agitated slides down the slope with a gradually increasing noise variously described, but the loudest tones of which are universally compared to distant thunder.

We have also particulars of two localities in Afghanistan both known as *Reg Ruwan* or *Rig-i-Rawan*, and of a locality in the desert of Sahara, Africa, where similar phenomena occur.

In conclusion we submit the following brief chronology of the subject.

*Chronology.*

| | |
|---|---|
| 16th Century. | Emperor Baber mentions sonorous sand. |
| 1808. | Dr. Seetzen hears reports of Jebel Nakous. |
| 1810. | Dr. Seetzen visits Jebel Nakous. |

| | |
|---|---|
| 1818. | Mr. Gray visits Jebel Nakous. |
| 1823. | Ehrenberg visits Jebel Nakous. |
| 1829. | Ehrenberg publishes his narrative. |
| 1830. | Lieut. Wellstedt visits Jebel Nakous. |
| 1836. | Sir Alex. Burnes visits Rig-i-Rawan. |
| 1850.(?) | Hugh Miller discovers Eigg locality. |
| 1854. | Kauai described by G. W. Bates. |
| 1855. | Prof. H. A. Ward visits Jebel Nakous (?). |
| 1868. | Prof. E. H. Palmer visits Jebel Nakous. |
| 1870–72. | Capt. Lovett visits Rig-i-Rawan. |
| 1875. | Dr. James Blake examines sand from Kauai. |
| 1876. | Dr. Meyn describes Bornholm. |
| 1882. | H. C. Bolton visits Manchester, Mass., and Eigg, Hebrides, and begins a monograph. |

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NOTICE ON THE MICROSCOPICAL EXAMINATION OF A SERIES OF OCEAN, LAKE, RIVER AND DESERT SANDS. By Dr. ALEXIS A. JULIEN, Columbia College, New York, N. Y., and Prof. H. CARRINGTON BOLTON, Trinity College, Hartford, Ct.

[ABSTRACT.]

THE results of an examination of over 320 samples — chiefly American — of sand from oceanic beaches, lake shores, river banks, deserts, etc., are given in detail. Marked differences of the light grayish color are found; yellowish tints are often produced by the intermixture of fragments of shell or of decomposing orthoclase; a black color by concentration of menaccanite; and reddish shades by abundance of garnet. In ordinary sands, such as those which lie above the high water mark on a sea beach, the grains rarely exceed one *mm.* in diameter, but in those of deserts are much finer, rarely exceeding half of one *mm.* In form there is, in general, great variation and but little observed rule; on rocky coasts, and in many river sands, angular forms prevail, and calcareous sands are apt to be extremely irregular in shape, as well as rather cellular in structure. In the constitution of the sands over forty distinct minerals or other substances were identified, the sands of the Atlantic coast consisting chiefly of the following:

| | | |
|---|---|---|
| Quartz, | Microcline, | Hornblende, |
| Chalcedony, | Albite, | Garnet, |
| Chert, | Menaccanite, | Shells and Corals, |
| Orthoclase, | Epidote, | Many rocks, etc. |

The more common accessories are the following:

| | | |
|---|---|---|
| Augite, | Beryl, | Kyanite, |
| Magnetite, | Rutile, | Zircon, |
| Tourmaline, | Titanite, | Anthracite, |
| Fibrolite, | Muscovite, | Silicified wood, etc. |

The constitution of the sands of lakes, rivers and deserts is much more simple. Oceanic sands are by no means so rich in quartz as generally supposed, the proportion of feldspar by volume, for instance, varying from 2 to even 38 per cent—that of menaccanite from 1 to 70 per cent, etc.

Many sands are peculiar in their constitution, sometimes even unique. Thus the sand of Nausett, Mass., contains much quartzyte; that of Nantucket, fragments of the various rocks of the moraine of the great glacial; many sands of the Rhode Island coast are rich in graphitic anthracite: that of Barnegat, in smoky quartz; many sands of New Jersey abound in chert, basanite, and sometimes beryl; the sands of North Carolina, and of the island of Eigg in the Hebrides, always contain silicified wood; those near Cape Hatteras are remarkable for their abundance of shells and the siliceous tests of diatoms and polycystines; those of Lake Champlain abound in the labradorite rocks of the Adirondacks; some sands of Hawaii appear unique in their great content of olivine; some sands of Lake Michigan enclose grains resembling fluorite; at the Great Salt Lake in Utah, the form of the calcareous grains is largely spherical, etc.

Of the entire number of samples examined, about 130 possessed the sonorous property on friction. Of these the great majority were remarkable for a certain degree of uniformity in size—usually about 0.3 to 0.5 *mm.* in diameter — general round form, polished superficies, and freedom from fine dust or minute feldspar fragments. Consequently they often present a characteristic oölitic or roe-like appearance, light color, and mobile condition. These characteristics are so marked and prevalent that it would be difficult to distinguish, without labels, specimens of sonorous sand from Mas-

sachusetts, Lake Huron, the Hebrides, or the coasts of Denmark and Prussia. At certain localities the sonorous variety has been found to present the decided features of a quicksand, and a general connection between these two facts is suspected to prevail wherever the conformation of coasts and oceanic currents permit the concentration of the sonorous sands below the high tide mark. A certain number of sands of special economic value, *e.g.*, in the sandblast, glass manufacture, mortar making, etc., have been examined to determine the characteristics to which their value is due.

August, 1884.

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A STUDY OF "EOZOON CANADENSE." FILED OBSERVATIONS. By Dr. ALEXIS A. JULIEN, Columbia College, New York, N. Y.

[ABSTRACT.]

A DESCRIPTION was given of the lithological characteristics of the rocks enclosing and associated with "Eozoon Canadense" at the following localities.

*Grenville*, P. Q., Canada, and certain localities of ophicalcyte in its vicinity.

*Petite Nation* (Côte St. Pierre), Can., visited during the last two summers, at the three important localities.

*South Burgess*, near Perth, Ont., Can., the locality of loganite, at which the occurrence and associations of Eozoon have never yet been described by any scientific observer.

*Thurman*, Essex Co., N. Y., a locality of serpentinous marble, containing what is supposed to be an imperfect form of Eozoon, but of which the petrographic phenomena have never yet been described.

Further facts were presented from a *new locality* for Eozoon, at Seillant's "apatite mine," several miles by the road from those known at Cote St. Pierre, but in the same seignory. The enclosure of pyroxene (or malacolite) within the serpentine was described, and a series of large specimens illustrated the general occurrence and mode of association. The apatite mines near Perth and South Burgess were, in this connection, represented by a few facts of interest and by photographs taken in the field, and specimens were exhibited from the "Soapstone Hill" near Rideau

lake, where the serpentine, associated with pyroxene, has been reported to contain Eozoon.

Farther reference was made to phenomena observed at an apatite mine near Côte St. Pierre and at limestone outcrops in that vicinity, in the dolomitic beds of Warren, New York and Westchester counties, N. Y., and in certain limestones of Orange Co., N. Y., and of northern New Jersey.

Specimens of the rocks and photographs taken in the field were exhibited to illustrate the observations made at most of these localities.

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NOTE ON THE INTIMATE RELATIONS OF THE CHEMUNG GROUP AND WAVERLY SANDSTONE IN NORTHWESTERN PENNSYLVANIA AND NORTHWESTERN NEW YORK. By Prof. JAMES HALL, State Geologist of N. Y., Albany, N. Y.

[ABSTRACT.]

THE general relations of the Chemung and Waverly groups are very well understood by geologists at the present time, but I am not aware that the absolute limitations of these groups at their junction has been fully shown, either by their physical or palæontological characteristics.

Those who have studied the Chemung group in its palæontological aspect regard the presence of *Spirifer disjuncta*=*S. Verneuili*, as marking its uppermost fossiliferous beds, and the presence of this fossil as reliable evidence of the age of the formation. All the investigations in southwestern New York, made by the writer, have hitherto failed to show the presence of the Waverly sandstone above the Chemung. Some of the conglomerates—as that of Panama—have sometimes been paralleled with the Waverly or Marshall group, and therefore regarded as of Carboniferous age. A more critical study of the fossils of these conglomerates has proved them to be of Chemung age, and their position in the upper member of that group.

In following the Chemung group in its exposures from Panama to the southwest, and beyond the limits of New York, we find the higher members to consist of a bluish shaly sandstone containing great numbers of separated valves of *Spirifer disjuncta*, which bear evidence of having been drifted and worn before em-

bedding. Associated with these water-worn and separated valves of Spirifer are shells or casts of Ptychopteria not dissimilar from the species abundant in the conglomerate of Panama.

Succeeding these fossiliferous beds comes a gray or bluish gray fissile shale, which graduates into a stronger dark colored or nearly black shale above. This shale, as exposed in a railroad cutting, presents a thickness of about thirty feet, but as no rock could be found above it, its entire thickness is unknown. Throughout the whole thickness examined it is totally barren of fossils of any kind—so far as observed—and its relations to the beds below are apparently only those of superposition. A careful examination of the country for some miles to the south and southeast of the locality mentioned failed to show any succession of beds above the dark barren shales.

This knowledge of the upper fossiliferous member of the Chemung group, and its relation to the non fossiliferous beds above, has been possessed for many years, but we have had no positive knowledge of the character of the strata or of the direct succession above this horizon until the present time. During this season Mr. C. E. Beecher of the N. Y. State Museum of Natural History has made an examination of the strata in the neighborhood of Warren, Penn., and with the information thus obtained, together with previous knowledge, he and Mr. F. A. Randall have constructed the section here presented to the association.

The section exhibits about 1500 feet of the upper members of the Chemung group, terminated by the barren shales and flags which correspond to those already described, and lie above the *Spirifer disjuncta* beds.

The first fossiliferous beds above these barren measures contain Crinoids, Syringothyris and Productus, but no specimens of any form of Chemung Spirifera has been found.[1]

List of Waverly Fossils.

| | |
|---|---|
| Cypricardinia | Productus, 2 species |
| Sphenotus. | Lepidechinus |
| Paracardium | Star fishes |
| Leptodomus | Tropidocaris alternata |
| Modiomorpha | 6 or 8 species of Crinoids |
| Modiola | 2 genera of Fishes |

[1] The accompanying generic list comprises the larger number of forms thus far known in this horizon. With our present knowledge it would be fair to assert that we have at Warren more than fifty genera and at least 200 species in the Waverly group between the Chemung barren measures and the Garland conglomerate.

| | |
|---|---|
| Leptodesma | Fenestella |
| Allorisma | Trematopora? |
| Aviculopecten | Platyceras |
| Crenipecten | Bellerophon |
| Lyriopecten | Pleurotomaria |
| Rhynchonella | Loxonema? |
| (Rhynchonelloid sp.) | Euomphalus? |
| Chonetes | Orthoceras |
| Streptorhynchus | Gomphoceras |
| Cyrtina | Gyroceras |
| Retzia | Dictyophyton |
| Syringothyris | Clathrospongia |
| Lingula | Ectenodictya |
| Crania | Spiraxis |
| Orthis michelina | Lepidodendron |
| Athyris | Chonostegites |
| | Fucoids |

In the succeeding beds, in the ascending order, the fauna assumes a more and more carboniferous aspect, leaving no doubt as to the proper reference of the beds of this horizon.

In the upper part of the conglomerate, and in the sandstones above it, the fossils are chiefly of land plants of the genera Lepidodendron, Sigillaria, Calamites, Halonia, etc., of large size and abundant in specimens.

The absence of the Catskill group or any beds which can be referred to that horizon is very significant.

Without any apparent want of conformity, the Waverly group follows the Chemung, but we know that at the point in the Section marked + "Place of Catskill" there is a hiatus which, in eastern New York and Pennsylvania, is marked by the presence of measures having a thickness of from 3000 to 5000 feet. Therefore we have a right to conclude that there has been a long interval in time between the final deposition of the barren Chemung shales[2] and the fossiliferous Waverly sandstone, or that the deposition of the estuary Catskill sediments has been going on simultaneously with the open sea deposits of the Waverly formation.

The results of these investigations, and the study of the fossils of these formations, have shown that there exists no conspicuous physical line of demarcation between them, and that the only reliable means of distinguishing them, lie in the careful study of the palæontological features of the two groups.

The entire section is too large and elaborate to accompany the present paper, but the principal features representing the strata under discussion are here given.

[2] It may be mentioned that fragments of the shells of *Spirifera disjuncta*, and some other fossils, have been found in these shales near Warren, Pennsylvania.

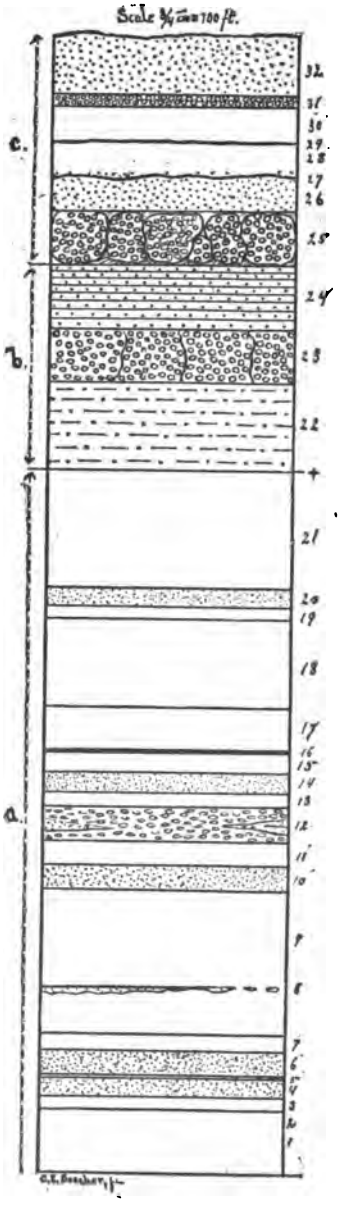
EXPLANATION OF THE SECTION.

*a.* Chemung group.

*b.* Waverly group.

*c.* Carboniferous.

1. Blue shale reaching to the level of the Alleghany river, and below.
2. Brown shale.
3. Red shale.
4. Massive gray sandstone.
5. Shale, mottled with red.
6. Massive green sandstone.
7. Shales and flags.
8. Sandstone, variable (mud-furrows).
9. Brown shales.
10. Massive sandstone.
11. Shales and flags.
12. Conglomerate flat pebbles (fish remains).
13. Shales.
14. Massive sandstones.
15. Shales.
16. Impure limestone.
17. Shales.
18. Flags.
19. Shales.
20. Massive fine gray sandstone.
21. Shales and flags (*Tropidocaris interrupta, Spirifera Verneuili*).
+ Place of the Catskill.
22. Shaly sandstones (Crinoids, Syringothyris passing into buff colored, friable sandstone).
23. Massive conglomerate.
24. Thin bedded, buff sandstones (Crinoids, etc.)
25. Conglomerate (Garland).
26. Massive, coarse, gray sandstone.
27. Quaker Hill coal bed.
28. Shales and flags (*Ctenacanthus*).
29. Coal beds three miles S. of Warren.
30. Shales.
31. Conglomerate (angular pebbles).
32. Massive white sandstone.



NOTE ON THE EURYPTERIDÆ OF THE DEVONIAN AND CARBONIFEROUS FORMATIONS OF PENNSYLVANIA; WITH A SUPPLEMENTARY NOTE ON STYLONURUS EXCELSIOR. By Prof. JAMES HALL, State Geologist of New York, Albany, N. Y.

THE presence of fossils of this family in the Devonian and Carboniferous formations of the United States, is of such rare occurrence that the fact is worthy of especial notice; and although the descriptions have already been published, the information may not improperly come before this association.

Although several species of this genus have been described from the Carboniferous rocks of Europe, the first published notice of Eurypterus from this system in America was given, under the name Erypterus (Anthraconectes) Mazonensis by Messrs. Meek and Worthen in 1868. In 1877 Mr. Charles E. Hall described a species from the lower Carboniferous rocks of Venango county, Pennsylvania, *E. Pennsylvanicus*, and another form from the coal measures of Cannelton, Pa., *E.* (*Dolichopterus*) *Mansfieldi*.

An examination of all the specimens proves these species to belong to the genus Eurypterus, presenting the generic form and structure, without any variation of sufficient significance to require sub-generic distinction. A critical examination and comparison of the specimens received from the geological survey of Pennsylvania has led me to the conclusion that three distinct species may be recognized from the coal measures, and a fourth species from the lower beds of the carboniferous system.

The single species from the Chemung group at Warren, Pennsylvania, is the only one yet known from the Devonian rocks of the country. This form is more compact, the swimming feet stronger, and the articulations less extended at their extremities, than those of the carboniferous horizon.

The geological range of the genus, so far as at present known, is from the Clinton group, where we have an unpublished species (*E. prominens*), to the Coal measures. Taking the Water-lime forms as typical of the genus, the only marked differences between these and the coal measure species are the comparatively greater elongation and more slender forms of the latter. The swimming feet and limbs, the operculum, and the mesial appendage, are similar in character. The segments of the body in the later forms

are sometimes more extended and acutely spiniform, but all these differences appear to be only of specific importance.

The accompanying table will show the geological range of the known species in the United States. The two most prolific horizons are the Water-lime and the Coal measures.

TABULAR VIEW OF THE GEOLOGICAL DISTRIBUTION OF THE FAMILY EURYPTERIDÆ IN THE UNITED STATES.

| | Waterlime. | Lower Helderburg. | Upper Helderburg. | Hamilton. | Portage. | Chemung. | Catskill. | Waverly. | Carboniferous. |
|---|---|---|---|---|---|---|---|---|---|
| *Eurypterus*, DeKay, 1825 | .... | .... | ... | .... | .... | .... | .... | .... | ... |
| *E. Beecheri*, Hall | .... | .... | .... | .... | .... | + | .... | .... | ... |
| *E. Dekayi*, Hall | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *E. Eriensis*, Whitfield | .... | + | .... | .... | .... | .... | .... | .... | ... |
| *E. lacustris*, Harlan | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *E.* " *var. robustus*, Hall | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *E. Mansfeldi*, C. E. Hall | .... | .... | .... | .... | .... | .... | .... | .... | + |
| *E. Mazonensis*, Meek and Worthen | .... | .... | .... | .... | .... | .... | .... | .... | + |
| *E. micropthalmus*, Hall | .... | + | .... | .... | .... | .... | .... | .... | ... |
| *E. pachychierus*, Hall | + | .... | .... | .... | .... | .... | .. | .... | ... |
| *E. Pennsylvanicus*, C. E. Hall | .... | .... | .... | .... | .... | .... | .... | .... | + |
| *E. potens*, Hall | .... | .... | .... | .... | .... | .... | .... | .... | + |
| *E. pulicaris*, Salter | .... | .... | .... | .... | .... | .... | .... | .... | + |
| *E. pustulosus*, Hall | + | | .... | .... | .... | .... | .... | .... | ... |
| *E. remipes*, DeKay | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *E. Stylus*, Hall | .... | .... | .... | .... | .... | .... | .... | ... | + |
| *E. tetragonopthalmus*, Fischer | + | .. | .... | .... | .... | .... | .... | .... | ... |
| | 16 | 7 | 2 | | | 1 | | | 6 |
| *Dolichopterus*, Hall, 18. 59 | | | | | | | | | |
| *D. macrocheirus*, Hall | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *Pterygotus*, Agassiz, 1839 | | | | | | | | | |
| *P. Buffaloensis*, Pohlman | + | .... | .... | .... | .... | .... | .. | .... | ... |
| *P. Cobbi*, Hall | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *P. Cummingsi*, Grote and Pitt | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *P. macropthalmus*, Hall | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *P. Osborni*, Hall | + | .... | .... | .... | .... | .... | .... | .... | ... |
| *Stylonurus*, Page, 1856 | | | | | | | | | |
| *S. excelsior*, Hall | .... | .... | ... | .... | .... | .... | .... | .... | |

## STYLONURUS EXCELSIOR, HALL.

Sometime about three years since the Museum of Rutgers College, New Jersey, received a specimen of the olive sandstone of the Catskill group containing the carapace of a large crustacean. The slab of sandstone is from Delaware County, N. Y., and having been split in the direction of the bedding, the fossil is carried in relief upon one side and the impression upon the other.

The carapace measures ten inches in length by eight and one-half inches in width across the palpebral arches, being a little less at the base. As compared with the larger specimens of *Stylonurus scoticus*, illustrated by Dr. Henry Woodward, our species has had an entire length of more than four feet.

The first published notice of this species appeared in the Transactions of the N. Y. Acad. of Sciences, Vol. II, p. 8, Oct., 1882.

The carapace is described and figured in the 36th Report of the N. Y. State Museum of Natural History.

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GEOGRAPHICAL AND PHYSICAL CONDITIONS AS MODIFYING FOSSIL FAUNAS. By Dr. HENRY S. WILLIAMS, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

RECENT studies of the fossil faunas of the Devono-Carboniferous series in New York, Pennsylvania and Ohio, have brought out several interesting facts, pointing to the necessity of recognizing the modifying effects of geographical and physical conditions upon species and faunas in order to the correct determination of their stratigraphic or chronologic position. Taking a well marked base, such as the Black Genesee shale, which terminates the formation bearing the Hamilton fauna and is recognized over a wide territory of rock exposures, the series of deposits filling the interval, up to the pre-carboniferous conglomerate, when studied serially from east to west, presents gradual but remarkable changes. So great are these changes that the meridional sections passing through Cayuga lake, Alleghany Co., N. Y., and Erie Co., Pa., present almost entire dissimilarity in the great part of their strata; while any one of these when compared with those passing through Otsego Co., New York, and Lake Co., Ohio, although occupying the same interval, presents such extreme differences that it seems to belong to a different formation.

By study of the fossils, dissecting, so to speak, the general faunas into their loco-temporal faunas, the nature of their modification from east to west has become apparent.

There are certain definite criteria marking the horizon over the whole region, such as the presence of certain widely extended species or the first appearance of faunas under similar conditions.

The lithological changes have been gradual, causing, not a thinning or thickening of the individual strata or rock masses, but a gradual increase or decrease of one class of deposits over another. For instance, a series of strata, in one place argillaceous, soft and fissile, will be found, a few miles distant, more arenaceous, the sandy strata occurring more frequently and thicker.

Or, certain beds of a peculiar character, thin and inconspicuous in one section, become conspicuous and dominant in another, so that a series of dark gray-green shales and sandstones become changed, in the course of a hundred miles, into a series of alternate soft, light green argillaceous shales, and black bituminous shales.

Or, higher up, brown-gray shales, with thin shaly sandstones, of one section are represented a hundred miles farther west by alternation of soft green shales and massive gray calcareous sandstones. With these lithological changes the fossils change; but in the case of the fossils also, the difference is rather in the frequency and prominence of certain species or varieties of species, than in any total replacement of faunas; though it is believed that a total change in the faunas themselves would result if the comparisons were carried far enough.

There is also an earlier appearance of some species in one part of the area than in another. Of this fact I have unmistakable proof. In the Portage group at Ithaca, as I have already shown, is a rich fauna, not equivalent to the Chemung, but intermediate between it and the Hamilton, which does not appear at all west of Cayuga lake. Again in Erie Co., Pa., in strata well down in the Portage, and in I. C. White's Girard shales, are found Rhynchonellas and other species which, in Alleghany Co., N. Y., do not appear till well up in the Chemung faunas. Many other details might be mentioned, all pointing to the one conclusion, that in passing over geographical areas of sedimentary deposits, of even a few hundred miles extent, especially when the direction is vertical to the probable coast line of the Period, the effects of those changed conditions recorded in the different nature and structure of the deposits, and of other conditions only recorded in the fossils themselves, which were probably differences of temperature and ocean currents, must be borne in mind in classifying the deposits. The confusion which our stratigraphers find, arising from the anomalous position of species and the apparent subversion of established canons, must be met, not by discarding the evidence furnished by fossils, but by giving them more close and thorough study.

ON SOME FISH REMAINS RECENTLY DISCOVERED IN THE SILURIAN ROCKS OF PENNSYLVANIA. By Prof. E. W. CLAYPOLE, Buchtel College, Akron, Ohio.

[ABSTRACT.]

THE rocks lying between the Medina and Oriskany sandstone in Pennsylvania (Fifth group of Rogers) consist of a vast mass of shales and limestones which have long been known to correspond in the main with the beds in New York lying between the Clinton and L. Helderberg. But their exact place had not been defined.

My recent work on the Palæontology of Middle Pennsylvania led me to attempt the correlation of these beds with those of New York on the evidence of their fossils. The conclusions with the facts on which they rest were embodied in a paper presented to the American Philosophical Society in March, 1884.

The following is a short summary of the contents of that paper:

The lower portion of these beds 900–1000 feet thick contains fossils described from the Clinton group of New York. It consists of green shales with sandstones and iron ore. The fossils thus far identified are *Beyrichia lata* Van., *Calymene Clintoni* Van., *Calymene Niagarensis* Hall, *Ormoceras vertebratum* Hall.

Beside this the evidence from lithology is very strong in the same direction. I have therefore no hesitation in referring these beds to the Clinton Group, which thus limited extends from the top of the Medina Sandstone to the top of an iron ore known in the district as the Sandvein Ore Bed.

Above this lie 150 feet of green shale and limestone which so far as I have yet studied them contain one or perhaps two Clinton species mixed with at least a single form belonging to the Lower Helderberg. The two that have been certainly identified are *Lingula oblonga* Hall, *Beyrichia notata* Hall.

These I have for the present called passage beds between the Clinton and Onondaga.

Above them lies the great mass of Red Shale, Variegated Marl and gray Marl about 1000 feet thick, forming the mass commonly spoken of as the shale of No. 5 of Rogers. Chiefly for lithologic reasons I consider this the equivalent of the Onondaga of New York, the description of which by Vanuxem precisely fits it. Palæontological evidence is slight but the beds have yielded me *Beyrichia notata* Van., *Leperditia alta* Con.

Overlying the Onondaga is a massive limestone very barren, but yielding in Juniata County the New York Crustacean *Pterygotus Osborni* Hall.

From this fact and the strong stratigraphic evidence, there can be no reasonable doubt that we have in it the equivalent of the water-lime of New York.

Lastly follow limeshales yielding L. Helderberg fossils and unquestionably the counterpart of the similar beds in New York.

The above is a very brief summary of the paper on this subject which may be consulted in the Proceedings of the American Philosophical Society for 1884.

It follows that in middle Pennsylvania no equivalent of the Niagara group exists.

The following is a table of the results above detailed:

COMPARISON OF UPPER SILURIAN ROCKS IN NEW YORK AND PENNSYLVANIA.

| | NEW YORK. | MIDDLE PENNSYLVANIA. | |
|---|---|---|---|
| Lower Helderberg Group | Upper pentamerous Limestone | | |
| | Encrinal Limestone | Flint Shale with Crinoids | |
| | Shaly Limestone | Limeshales with Tentaculites, Meristella, etc. | |
| | Lower pentamerous Limestone | | |
| | Waterlime | Limestone with Pterygotus, etc. | |
| Onondaga Group | Magnesian and vermicular Rock | | |
| | Gypseous Marls | Grey Marls | No. V of Rogers |
| | Variegated Marls | Variegated Marls | |
| | Red Shale | Red Shale | |
| | | Passage beds | |
| Clinton Group | Limestone | Limestone and Ore | |
| | | Sandrock | |
| | Iron Ore | Ore | |
| | | Sandrock | |
| | Upper green Shale | Upper green Shale and Ore | |
| | Limestone and Ore | Iron Sandstone and Ore | |
| | Lower green Shale | Lower green Shale | |
| | Medina Sandstone | Medina Sandstone | |

Most of the fossils alluded to in the sequel of this paper were found in the variegated shales of the Onondaga group—an horizon below those which have yielded the oldest previously known fish remains in America and at least as old as the lowest fish-bearing rocks elsewhere. The exact stratum is a bed which I have named the Bloomfield Sandstone from its exposure near the town of New Bloomfield in Perry County and which lies at the top of the variegated shale of the Onondaga about 200 feet below the water lime.

The fossils themselves are of two kinds. First, or least abundant, are small spines apparently of Selachian fish much resembling those described from the Ludlow rocks in England. These by their form and appearance admit of no doubt concerning their nature. Second, are a number of flattish, elongated, striated shields whose appearance instantly suggests a relationship to the well-known *Pteraspis* of the same rocks. Nor is this appearance delusive. Closer examination confirms the first impression in every point and leaves no room for doubt that these Onondaga shales, so barren of animal life, contain older vertebrate fossils than any previously described from this county.

To confirm these conclusions, microscopic evidence can be cited, if necessary. Thin sections cut and mounted in Canada balsam show, not indeed the ordinary structure of bone, which is totally wanting, but a structure so closely resembling that of the Ludlow *Pteraspis* that the near affinity of the two is placed beyond question.

Sufficient differences, however, exist both in the outer shape and the minute structure, as shown by my own specimens of both the English and American fossils and by a comparison of the latter with Prof. Huxley's figures as given in the Quarterly Journal of the Geological Society (August, 1858), to enable me to distinguish between them, both as genera and species, and I propose for the fossils now brought forward the generic name *Palœaspis* and in this new genus I place the two following species: *Palœaspis elliptica*, *Palœaspis bitruncata*.

For the species previously mentioned I propose the name *Onchus Pennsylvanicus*.

It is not possible in an abstract like this to enter into minute details of description and structure. These must be reserved for another place.

But in regard to the age of these fossils compared with that of

the *Onchus* and *Pteraspis* of the English beds, I may say that in the Table given above the Ludlow beds are palæontologically considered the equivalent of the American Lower Helderberg and Waterlime and that in consequence the fossils they contain must be stratigraphically younger than those which I here bring forward from strata at least two hundred feet lower down. Only a single specimen has yet been found from the *Lower* Ludlow in England. All the rest came from the Upper Ludlow about 1000 feet higher up.

Shortly after the discovery of these fossils, when working in the Red Shale of the same county and about a thousand feet below the Bloomfield sandstone, I met with a thin bed consisting in great part of what appeared to be the comminuted scales of fish. Their broken and fragmentary condition has thus far prevented my making a successful study of these, but I cannot from their general appearance and structure entertain much doubt that they are also fish remains and I strongly incline to the view that they are coprolitic in origin. This carries the existence of fish down nearly to the base of the Onondaga group.

Further, on the same day I discovered another layer crowded with fragments presenting an appearance very similar to that just described, but at least 500–600 feet lower still. Though in broken condition and from the refractory nature of the matrix exceedingly difficult to extract or examine, yet their appearance is enough to satisfy me that these also are comminuted fish plates or scales bearing in many cases the characteristic sculpture on their outer faces. There are also with them a few imperfectly preserved spines similar to those found in the Bloomfield Sandstone. Coming as they do from the Iron Sandstone they carry, as will be seen by reference to the Table, the existence of fish (and therefore of Vertebrates?) back nearly to the middle of the Clinton Group and consequently to an horizon considerably lower and older than any that have hitherto yielded fish remains in America or elsewhere.[1]

Into the zoölogical affinity of *Palœaspis* this is not the place or time to enter. Its resemblance to the English *Pteraspis* is so close that the two must stand or fall as fish together. Regarding

[1] It is perhaps right to add that in thus speaking I exclude the much disputed "Conodonts" of Prof. Pander from the *Lower* Silurian rocks of St. Petersburg. Should these bodies prove the remains of fish they are of yet older date.

the latter, Huxley says (Q. J. G.. S, Aug., 1858): "No one can, I think, hesitate in placing *Pteraspis* among fishes." In this preliminary notice I claim no more than the admission of *Palœaspis* to the standing which has been accorded to *Pteraspis*. I shall hope on some future occasion here or elsewhere to state some of the details at greater length.[2]

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GEOGRAPHIC CLASSIFICATION, ILLUSTRATED BY A STUDY OF PLAINS, PLATEAUS AND THEIR DERIVATIVES. By W. M. DAVIS, Harvard University, Cambridge, Mass.

[ABSTRACT.]

THE relations of a number of geographic forms may be exhibited by means of a classification based first on the peculiarities of structure and second on the amount of erosion that they have suffered. Conditions of accumulation, elevation and deformation give subheadings under the first class, while the stage of advance in the destructive processes of erosion that cut all land forms alike down to a base-level plain of denudation provides further opportunity for subdivision. In no group of forms does this method of classification find better illustration than in those characterized by a structure of horizontal layers.

This great group may be first divided and subdivided according to special conditions of formation and composition; thus we have

(*a*) Strata of fragmental or calcareous materials of marine, lacustrine, fluviatile or æolean origin, all of common occurrence.

(*b*) Sheets of overflowing lava, greatly expanded in Idaho and India, less in France and Germany.

(*c*) Ice and snow plains, still existing in Greenland, and of special interest there as representatives of the vast snowy desert that spread in relatively recent times over the lands about the North Atlantic.

(*d*) Salt plains, deposited by evaporation of inland lakes.

(*e*) Peat and other vegetable deposits, accumulated by organic growth. These last two divisions include deposits generally of relatively small area and short duration, which gain a long life only when preserved by burial.

[2]For further details on this subject see the Q. G. J. S., for February, 1885.

The means of revelation or birth of such of these deposits as are formed beneath water affords further ground for their classification. The greatest number have been (*a*) directly lifted out of water by an upheaving force of unknown origin that acts vertically without any superficial appearance of lateral crushing, as in the Colorado and other plateaus. Corresponding closely with this, and perhaps in some regions of moderate elevation confounded with it, is (*b*) the laying dry of shallow sea-bottoms by the deepening of the ocean elsewhere. The sheet of water has been withdrawn from lake deposits (*c*) by evaporation, (*d*) by cutting down outlet, probably in some cases (*e*) by tilting the basin so as to allow better drainage, and (*f*) by melting away of barrier, as suggested in the case of Lake Agassiz and very many small glacial lakes. The water has been (*g*) displaced by delta and littoral deposits.

But of greater geographical importance than these early and constructional characteristics, are the later, destructional ones, determined by erosion, inasmuch as they comprehend the topographical form that we actually observe. It is this division of the subject that is worthy of most attention from the comparative geographer, and in assigning a region of horizontal structure to its proper place in this classification, the following sketch of the life-history of such a land mass may serve as a guide. Just as the surface of the deposit rises above its base-level of erosion—or, in the case of lake deposits, as the governing base-level sinks below the surface, a smooth, unbroken plain is revealed. Its drainage is imperfect, for the newly formed streams have not yet had time to establish their channels, and much of the rainfall stands on the ground until it evaporates. Faint depressions on the surface, the effect of slight irregularity in the original distribution of the deposit, hold the water back to form shallow marshy lakes. The smoothness of the surface and the shallow lakes are indeed truly infantile features, retained only during the earliest life of the plain, and soon lost in its further development. This development finds its opportunity in the gaining of an effective elevation above the base-level of the region and in the persistent down-cutting of the streams. Rivers establish their courses, the smooth plain is trenched across by their meandering channels, and all the lakes disappear. This is adolescence. The channels will be narrow and steep walled in regions of relatively rapid elevation, but broadly open in regions that have risen slowly, and I believe that

rate of elevation is thus of greater importance than climatic conditions in giving the cañon form to a valley. Of course the channels must be shallow in plains of small altitude, while they may become deep in regions that have been raised to a great height; but great cañons can occur only in young plateaus, for cañons are marks of a precocious adolescence, and in this feature, the Colorado plateaus are truly American. Adolescence as thus defined includes that part of a plateau's early life in which the stream channels are narrow and well marked; but as the valleys increase in number and open widely so as to consume a good share (one-sixth to one-fifth) of the plateau mass measured above the existing base-level of discharge, then adolescence merges into maturity. Maturity may be said to last through the period of greatest diversity of form, or maximum topographic differentiation, until about three-quarters of the original mass are carried away; and through this period when the geographic names for this group of forms should be most applicable, there are none whatever that can be properly applied, nor is there any that includes this group of forms as a whole.

During maturity no vestige of plain surface remains (except in slow-rising, low plains that never acquire any marked relief), and the region is too broken to be named a plateau. To call it a hilly or mountainous country resting on a plateau would be an unappreciative, indeed a vicious, style of nomenclature. Indeed there is no suitable technical name yet proposed for such a surface, although it possesses a most peculiar and well-defined topography. Long lines of cliffs are the most pronounced features; their upper edge is of constant altitude, but their direction is exceedingly irregular, continually varying as they pass from reëntrant to projecting angles. When standing on the bench or platform of such a cliff, its extension can be traced for miles, contouring around the spurs that separate ravines and valleys. Every cliff marks the outcropping of a more resistant stratum or group of strata than those that over and underlie it, and the natural variety in the sequence of harder and softer layers gives origin to the many variations on a single type that are observed in the scenery of broken plateaus. The cliffs are separated by sloping surfaces, that in the younger plateaus are steep and largely covered with debris from the cliff above, forming a talus almost down to the cliff below; but with the recession of the cliffs, the talus proper is restricted

to a narrow space around their base, and the intervening bench land has a more gentle inclination.

Along the larger valleys, outliers are frequently isolated from the main plateau mass by the meeting of side streams behind them; these are often used as strongholds by savage tribes, and as we know in the west the cliffs also may afford protection to weaker races who seek shelter beneath them. The models of these peculiar dwellings, prepared by Messrs. Holmes and Jackson of our geological survey, illustrate admirable examples of the control exerted by topography on the conditions of human life. During the maturity of a plateau all the streams cut down nearly to their base-level and give a maximum of relief between the upper levels and valley bottoms. The stream system itself is very characteristic: the stream courses having been selected on nearly horizontal surfaces, and finding no lateral constraint in the attitude of the strata through which they cut, are necessarily meandering; they branch and subdivide in all directions, like the veins of a maple leaf, giving a consequent irregularity to the outcrop of hard strata on spurs and in ravines, and rendering a well-broken plateau extremely difficult to traverse. No small degree of skill and experience is required to extricate one's self from the labyrinth of almost impassable valleys in crossing such a country.

One of the latest phases of maturity reveals the higher levels of the plateau broken through by the ever increasing number of ravines and valleys, producing in some cases the peculiar pinnacled topography in which vertical lines are so numerous and so pronounced that it is at first difficult to associate them with a horizontal structure; but the pinnacles are simply remnants of the cliff faces that first appeared as bold steps on the valley slopes, that were next seen wrapped around the gradually isolated outliers, and that now still retain their height, while their length has diminished as the outlier wasted away.

On leaving this stage, the plateau passes from maturity to old age: the relief of the surface diminishes, for while the pinnacles dwindle away and the country loses in altitude, the valleys do not correspondingly gain in depth. The cliff faces are forced farther and farther back and the valleys increase greatly in width, the slopes become gentler and the whole aspect of the region is simpler and tamer than before. The kernels of the longest enduring outliers stand scattered about on the low plains into which the all-consuming

valleys have grown and fitly take the form of great fortresses in their final struggle against the elements. At last even these remnants are carried away, reducing the once rugged country to almost as low, flat and featureless a surface as it was at birth; but its perfected system of meandering rivers separates it from newborn plains, and although now smooth when compared to the ruggedness of its maturity, still it rises gently between the streams in faint swells which distinguish it from the more nearly perfect level of unworn surfaces. It is now easy to traverse, but is still capable of misleading the traveller over its monotonous expanse, where every trough is closely like its neighbor, and all the intervening swells are too smooth and low to serve as landmarks or as points of view. This is simple old age, a second childhood in which infantile features are imitated and thus the decrepit surface must wait either until extinguished by submergence below the sea, or regenerated by elevation into a new cycle of life.

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THE GENESIS AND CONSERVATION OF VOLCANIC ENERGY. By Prof. J. W. PIKE, Vineland, N. J.

[ABSTRACT.]

MR. FARADAY has truly said, "no hypothesis should be admitted nor any assertion of fact credited, that denies the principle" of conservation of force; and any apparent conflict of our theories with this principle points to undiscovered laws and conversions of force. Our principal hypothesis of volcanic energy is a speculation of cosmogony, and derives it from an expiring remnant of the earth's primordial incandescence still retained in its interior. The antecedent form of this primal heat is supposed to have been the motion of falling nebulous particles, attracted together to form the globe. But this does not quite agree with the doctrine of conservation, for gravitation which is thus made the antecedent form of the motion is not convertible. Gravitation, chemism, inertia, elasticity, etc., being properties of matter can only give back again the energy they have received. The antecedent form of the motion of the arrow is not the elasticity of the bow, but the muscular energy that bent it. As the antecedent form of the motion of

falling nebulous particles, we require an expanding, dissociating, nebula-producing force, like the solar energy which produces clouds in the atmosphere. But, according to the premise of our volcanic hypothesis, this is the same amount and kind of energy which the solar system has given away without compensation to the external universe, till only an insignificant fraction of the original dower remains. The analogies of nature and the law of conservation are better satisfied by postulating that the radiant energies of the sun and stars are not poured out forever into an infinite waste and lost, but are conserved, latent, by effecting nebulous dissociations of matter scattered in space. We may conceive a system of equitable cosmical exchanges, between the solar system and the stellar universe, in the currency of living energy which never perishes and never can be lost. We may hope to discover that not only forces, but falling comets, meteors, invisible nebulous masses and particles are returned as an equivalent for the radiant energy and dissociated material which our system imparts to its environment.

Similar reasoning would lead us to reject the idea that volcanic energy is the expiring remnant of primordial incandescence, and substitute the idea that it arises from the conversion of some latent form of force which is continually restored to the earth by geological processes. Accumulating knowledge steadily leads in the same direction.

It was an obvious deduction that such an incandescence would separate the water and all gases into a great external atmosphere; that the lighter molten layers would float upon the heavier and congealing into a crust, would divide all explosive gases from the anhydrous molten interior. But how could such lava be erupted through a crust light enough to float upon it, and how could it become explosive by further cooling? Plication from cooling and the opening of fissures from the nucleus to the sea bottom are plausible, but further examination increases the difficulties and leads to the conclusion that volcanic energy is the *cause* and not the effect of plication. The welding pressure of the deeper layers of the crust must make them impervious, and exclude water and all explosives from the molten interior. To escape the difficulties, Mr. Osmond Fisher would derive volcanic steam and gases, as well as heat, from the same primordial store, laid up in the earth's molten interior from the beginning.

Continued cooling should thicken the crust and make eruptions more difficult; the vast expenditure of explosive energy through the eons of geological time should make eruptions more and more feeble. Krakatoa and the Tertiary volcanoes are sufficient answer.

Prof. Hitchcock has suggested that the best situated passages, once opened to the molten interior, would continue to "exist and enlarge at the expense of the others," and we must add, *no new ones could be opened*. Continents would have the structure of volcanic islands, the volcanoes central and remote from the sea. On the contrary, we find volcanoes, not where denudation has penetrated nearest the supposed primordial heat, but, in the fringes of sediment where it is buried deepest.

Herschel's hypothesis, that sediments are fused, and their included water and gases made explosive by heat from beneath, we must regard as a great step forward. It fixes the attention upon new classes of facts, and organizes evidence before contradictory. Prof. Hall has pointed us to great accumulations of sediment as the sources of disturbance. Dr. Hunt, to a deeply buried water-impregnated zone of plastic sediments as the probable source of volcanic ejections; and with Le Conte, Judd and others, has explained how great accumulations may, perhaps, produce "lines of weakness," and by the supposed contraction of the nucleus, the upswelling of the lines into mountain chains. Scrope's conclusion, so ably stated by Captain Dutton, is fairly reached. "Volcanic phenomena are brought about by a local increase of temperature within certain subterranean horizons." The steam, gases and molten rock erupted from volcanoes were once prepared and laid down by the processes of denudation and sedimentation.

I go a step further, and suggest that the volcanic energy was, in good part, also laid down latent in the sediments—that its antecedent form was the solar energy which disintegrated the older crystalline rocks out of which the sediments were formed; and that it is liberated by the metamorphism which reproduces, in plutonic depths, the equivalent crystalline rocks.

This is a modification of Keferstin's chemical hypothesis, published fifty years ago, and brought to the attention of American geologists by Dr. Hunt nearly twenty-five years ago. Volcanic phenomena, according to Keferstein, originate in known sedimen-

tary formations, "where they are the result of a peculiar kind of fermentation," which crystallizes and rearranges the elements of the sediments "with evolution of heat as a result of the chemical process." Crystallization also evolves heat.

Prof. LeConte admits chemical action as one of the sources of heat and so of a few others. But geologists commonly dismiss chemical sources by a brief reference to Davy's exploded notion of a combustible nucleus of light metals.

Volcanism has arisen from beneath great and rapidly accumulated beds of sediment. It is now active under *recent* accumulations. That these are also massive is indicated by their position, as those of Java, in the basin between two continents where the accumulations must be immense. Similarly those of Alaska, of Central America, the Mediterranean, and the Cretaceous sea that once divided North America. It is manifested along the sea border because there are the new sediments. The volcanic areas of remote geological periods were under sediments that were then new, and that were also then on the sea border—those of the Silurian, in sediments that were recent in Silurian time and on the Silurian sea border and so on. We can predict that this order will be found in the unexplored regions, and that no new volcanoes will ever break forth in old formations, or in continental areas. The obvious meaning of these facts is, that the energy arises from the sediments. When accumulated in sufficient quantity, and subjected to sufficient pressure, they will not keep, but "ferment"—undergo metamorphism, evolving their included gases and latent heat, as inevitably as a moistened haystack undergoes spontaneous combustion.

The nucleus cannot act where it is not. Each layer of sediment was once the surface, and had its temperature. The temperature of the surface is augmented only one-twentieth of a degree (F.) by escape of heat from beneath. Herschel's hypothesis requires us to suppose that cold layers being spread on, so prevents the escape of this one-twentieth that it finally fuses rock. If volcanic heat came from the interior, the supposed "lines of weakness" would be lines of strength.

The warrant for assuming that the antecedent form of volcanic force is the solar energy that crumbled the old rocks into sediments, is on the surface of nature and in the deepest generalizations of

science. A block of ice, differing from water as granite differs from mud, is disintegrated by solar energy, which is conserved latent in the water product, and evolved again by the metamorphism of the water into ice. Carbon-dioxide is disintegrated into carbon and oxygen in the plant leaf, and the solar force so expended reappears as heat and light when the carbon-dioxide is reproduced. According to thermo-chemical laws, the energy required to disintegrate a compound is the measure of the stability of the chemical union, and, at the same time, of the heat evolved by the combination. Great energy is absorbed in disintegrating granite into mud, therefore great heat will be given off when mud transforms to granite.

The sun is the "tooth of time" that crumbles mountains. It acts indirectly, through organic substances in the soil and in sea mud, to digest minerals or to advance them to the verge of solution. But, just as in the photographic process the silver compound requires a developer to complete the disintegration which the light has begun, so the force latent in the crumbled mineral may remain inert till subjected to plutonic conditions.

This included latent energy ensures the continued existence of an active plastic layer under deep sediments, and the "aqueo-igneous softening or even melting, not only of the lower portion of the sediments themselves but of *the underlying strata upon which they were deposited*,"—a process so well described and sustained by Hunt, LeConte, Dutton and others. This has been the earth's structure from the beginning of geological history, and subsidences and upheavals have been constantly in progress. Sediments having subsided under the sea, where there is no drainage, necessarily include much water. At the depth of from five to twelve miles they are subjected to enormous pressure, "and in pressure" as Powell remarks, "we have conditions for chemical change analogous to the conditions produced by melting."

The *most stable* compounds are formed, and great heat evolved thereby; the water is raised above its critical point, and the mud, dissolved in it without material absorption of heat. Crystallization sets in, and *the hardest* and most condensed minerals being formed, there is further great increase of temperature. Deposits of carbon, petroleum shales, etc., combining with the oxygen dissolved in the water substance, or partially reducing peroxidized metals,

still further augment the temperature. There is the greatest possible economy in these operations—more even than in the chemical reactions in the animal body. When quicklime combines with water great amounts of heat are lost by radiation and the expansion of part of the water into clouds of steam. Combustion in the open air is attended with still greater waste from radiation, conduction, convection, expansion of the combustion product, and the heating of four parts of nitrogen to one of active oxygen. But in plutonic reactions there is wonderful conservation, loss from conduction only remaining, radiation and convection being cut off, and all the products being prevented by the pressure from expanding. Beds of limestone being dissolved, the lime unites with silica and alumina to form pyroxenic minerals; while the carbon dioxide, water and other components of the atmosphere—dense as liquids—are continually excreted into the mother liquor, or ground mass, as the crystallization proceeds, which thus becomes more and more explosive. If portions of the magma are forced out during the earlier stages, it will probably be an intermediate or undifferentiated lava like andesite, and great explosive energy and much ashes exhibited. The cover of the active "fire sea" will be made of beds of gneiss followed above by mica schist shading into the unchanged beds in the regions of diminished pressure nearer the surface.

The magma may, in the lapse of a volcanic cycle, undergo differentiation. Pyroxenic minerals may sink, and acidic minerals may float up through the mother liquor, as suggested by King. The excreted, explosive ground-mass, being lighter than the overlying strata will force a passage to the surface and discharge its steam and gases, a proportion of the crystals necessarily floating up in it. Great quantities of acidic and granitic magma, becoming lighter, may be squeezed up as the core of a range from beneath the heavier subsiding rocks of the adjoining basin, as explained by Dutton.

The slowly rising colloid mass will plicate the overlying beds, coming between their edges like a vast dyke, and pushing them laterally from the axis of the growing chain, while the region is slowly rising out of the sea, and while eruptions are frequent in beds still above. Richthofen's "natural order of succession of volcanic products," is the necessary outcome of these operations.

If this chemical hypothesis is sustained by future research, our view of the earth's system of circulation—of waste and repair, compensation and recuperation becomes more and more grand and complete. The wasted land is perpetually renewed from the sea bottom. The carbon dioxide and with it the vital oxygen—the food of plants and the life of animals—are perpetually restored again to the atmosphere. The gems and minerals that are destroyed by time are perpetually renewed from their dust. The earth's interior is being heated in some areas, while it is cooling in others. The sun is seen to be a source of life to the earth as well as to plants and animals. There arises from the contemplation that broader, deeper view, which inspired Hutton to declare that "the Author of Nature may put on an end, as he no doubt gave a beginning to the present system;" but we do not discover that any germs of destruction have been planted in the constitution of things.

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BRITISH EARTHQUAKES AND THEIR SEISMIC RELATIONS. By Prof. RICHARD OWEN, New Harmony, Indiana.

[ABSTRACT.]

IN Mallet's "Catalogue of Earthquakes", 399 are recorded as having occurred in Great Britain, between the year 1042 and 1842. This includes those occasions during which Comrie, in Scotland, was shaken, thus making an average of about one for every two years.

The object of the present paper is to show that as many as 315 of these, or nearly three-fourths, are more or less connected with a G. C.[1] passing from ever-active Stromboli, through the pole of the land hemisphere at Monte Rosa (Switzerland) skirting, on its way, the east coast of England, and traversing in its northerly course the middle of Scotland; thence reaching Iceland. The probability of this connection, the paper undertakes to prove, by giving the approximate synchronism of other localities along that line, when *eastern* Great Britain is agitated.

In order to make these facts more clear, the unabbreviated paper

[1]As in former papers, a great circle of the earth is abbreviated to G. C.

gives a synopsis of eight continuously active volcanoes (Sangay, Fogo, etc.); fourteen of the best known remittingly active (such as Bourbon, Santorin, Etna, etc.); eight prehistorically active localities, as proved by geological evidence (Eifel, Auvergne, N. W. Scotland, etc.) and eleven or more land areas, or volcanoes, suddenly elevated, during the historical period: *e. g.*, Ullah Bund, in the Cutch, Jorullo, Monte Nuovo and the like.

The paper then examines in detail the peculiar position of forty places or more, that are either noted for the frequency of their earthquakes, as Caracas, Scios, Smyrna, etc., or for earth tremors sometimes continuing almost daily for months, such as occur at Comrie in Scotland, Janina in Epirus, Lunröe in Norway, Comorn in Hungary, etc., places generally situated at the intersection of two seismic G. C's, and at the outcrop between two different geological formations.

An additional object will be to show that the remaining eighty-four British earthquakes of that period, in Mallet's Catalogue, were probably influenced by the passage through Great Britain, or proximity to its coasts, of four other seismic G. C's. The tendency of seismic movements to follow G. C's is shown in my paper on Seismology, read at the Montreal meeting[2]; also in a communication to the Scientific American Supp., when discussing the earthquakes of 1883[3]. These G. C's denote activity, along the belt, as frequently through evidences of *upheaved*, as of *depressed* or fractured zones. In fact, whenever land is elevated, there must be a consequent sinking at no great distance, either longitudinally or laterally: *e. g.*, the elevation of Europe and Asia, necessitated the Caspian Sea depression; the gradual rise in northern Scandinavia compelled the gradual sinking along the northwest coast of Europe.[4] The present unabridged paper gives in detail the topography and geology of those five G. C's, of which the following abstract may offer some idea.

1. The Azores-Asonoyama belt. *Topography:* A G. C., passing from the initial focus of land-forming in Norway[5], and running S. 30° W. toward the N. W. coast of Scotland and Ireland, coin-

[2] See Vol. XXXI, Pt. 2nd, page 330 *et seq.* of Proc. A. A. A. S.
[3] Issue of March 29, 1884.
[4] See map page 26 of Reclus "Earth".
[5] Vol. XXIX, Part 2nd, page 441 *et seq.* Boston Proc. A. A. A. S.

cides with the average parallel fissures laid down by the late Evan Hopkins, C. E., on his map of Great Britain, as the direction of "*old* lamination of rocks, cleavage planes, etc."[6] It connects the Azores with the volcano of Asonoyama and others in S. Japan; and, in conjunction with the other radii from the Norwegian focus, aided in giving configuration to the Scandinavian Peninsula.

The *Geology* of this G. C. chiefly marks the junction between Archæan and Paleozoic in Scotland[7], Ireland and the mountains of Brazil (Paleozoic).

2. The Orizaba-Ormuz belt. *Topography:* This G. C. which radiates N. 30° W. from Tatra, the geographical centre of Europe,[8] passes through Newcastle-upon-Tyne (probably causing the 90 fathom dike), Isle of Man and Northern Ireland, reaching the region of Orizaba and other Mexican volcanoes. Extended from Tatra S. 30° E., besides passing through the extinct volcanic region of Armenia, and the oft-shaken towns of Persia, it reaches the volcanoes of the Persian Gulf.[9] This G. C., in passing through G. Britain, accords with Hopkins' average lines marked "direction of *old* fractures:" they run at right angles to the cleavage planes of No. 1.

*Geology:* The G. C. from Tatra, especially southeasterly flanking the Carpathians and northwesterly along the Sudetes, Riesengebirge, etc., marks the junction between Mesozoic and Cenozoic, (Cretaceous and Tertiary), while the northeasterly and southwesterly radii trace mainly Cretaceous areas.

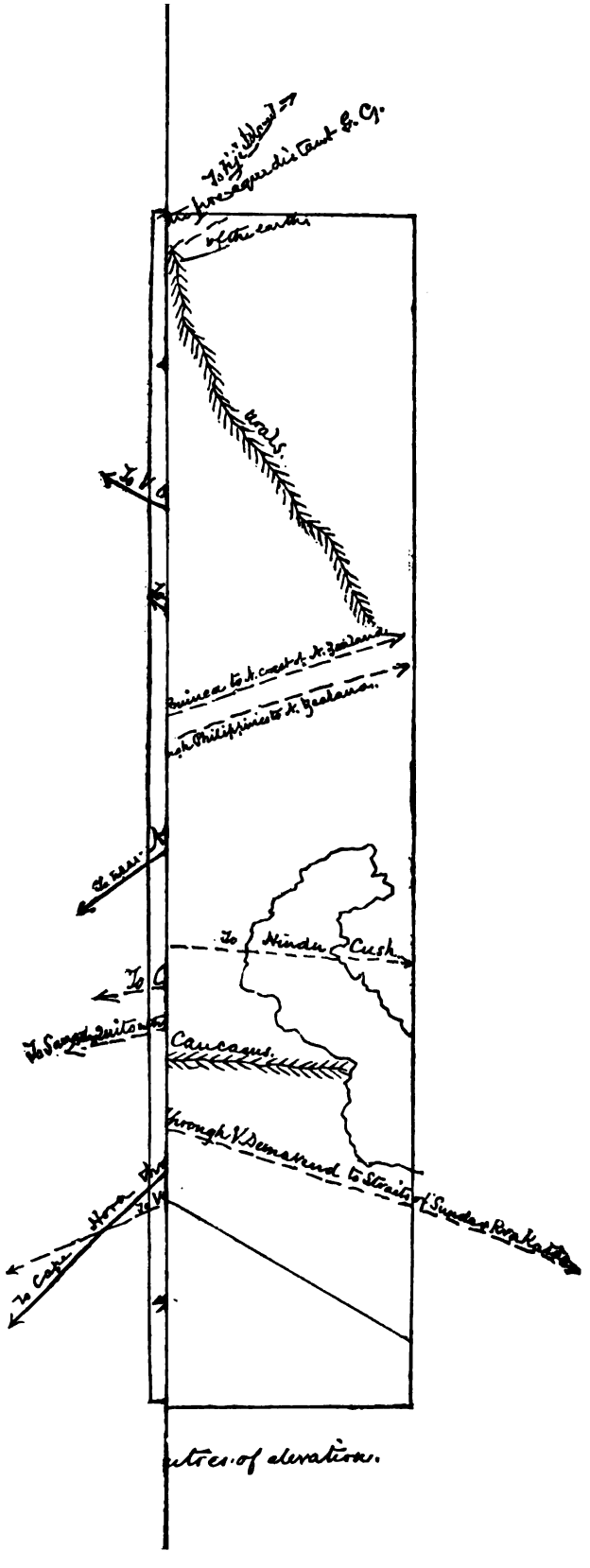
3. The Stromboli-Heckla belt. *Topography:* This most important G. C. radiates from Mt. Rosa N. 30° W. through Belgium, E. England (Colchester, Lincoln and York mark the medium strand of the belt) through Perthshire in Scotland and reaches Iceland. From Rosa, S. 30° E., it passes near the W. coast of Italy, to the Lipari Islands, including Sicily and Calabria in the belt. The lines on Hopkins' map which correspond in direction with this G. C. are marked as "direction of *recent* cross courses and splits."

[6] Hopkins' Geology, page 51 and map on Plate VI.

[7] For the former geographical connection between Norway and Scotland, see pp. 110 and 111 of A. Geikie's Geol. Sketches, also the map in the Text book, p. 450 of A. Geikie, Director Brit. Geol. Survey.

[8] Boston Proc. A. A. A. S. p. 441 *et seq.*

[9] Laid down at Mallet's Map as being near Straits of Ormuz.


To Hindu Cush
Caucasus
Through V. Demavend to Straits of Sunda
To Cape Horn
tres of elevation.

*Geology:* Cenozoic, as it has mainly brought Tertiary to the surface in Sicily, along the flanks of the Apennines; also at Berne, Bâle, in Belgium, Lincolnshire (England) and Yorkshire even beyond Hull.

4. The Santorin-Colima belt. *Topography:* Emanating from Rosa N. 60° W. this G. C. traverses France and the S. W. of England, and extends to Mexico, somewhat North of the volcano Colima; running South 60° East, it connects Janina with Santorin.

*Geology:* It marks Tertiary in parts of Greece, in Thessaly and Albania (Turkey), in Lombardy (Italy), at Dijon, Orleans, etc., in France.

5. The Fogo-Tongariro belt. *Topography:* This is one of the equidistant continental trends,[10] which, passing near the volcanoes of Tongariro[11] in New Zealand, skirts the east coast of South America, traverses the ever active Fogo, the Canaries, the submarine volcanic area in the Atlantic, the earthquake region of Lisbon, and is prolonged through the Bay of Biscay, N. W. coast of France and Belgium to Denmark, etc. It coincides, in its general trend with the lines marked by Hopkins, in his map of G. Britain, as "the average direction of most recent fractures, lodes, etc."

*Geology:* Its geology is chiefly Cenozoic in the Cape Verd and Canary Islands, Valadolid (Spain), Valleys of the Adour, Garonne and Seine (France), portions of Belgium, Holland and Denmark, indicated on Sir. R. Murchison's map of Europe as Miocene Tertiary.

### APPROXIMATE SYNCHRONISM.

To prove the synchronism, the paper enumerates fifty, or more, dates of British earthquakes on these G. C's with simultaneous earthquakes (or those at least approximately synchronous with the British shocks) at other places along the same line. In an abstract only a few examples can be given:

*Approximate Synchronism. I. On great circle No.* 3.

A. D. 1186. Middle Sept. England, Calabria and Malta.
1426. Sept. 29. Great Britain and Naples.

[10] Described in Boston Proc. A. A. A. S. at page 339.

[11] Stated in Reclus' Earth, page 438, to be constantly active. Kerry Nichols, from a recent personal ascent of Tongariro, gives the same testimony, in his work on the "King Country" of N. Zealand.

1731. Oct. 17, Naples; Oct. 19, Northamptonshire; Oct. 21, Northamptonshire and Bloxham.

1750. Sept. 3, Lincoln and Nottingham; Oct. 11, From Lincoln to Northamptonshire; same date Italy, Naples.

1792. Mch. 1, Doncaster, Nottingham, Stamford, Lincoln, Leicester, Bedford, all at same hour.

1818. Feb. 20, Lincolnshire, Catania, Calabria and Malta; Etna quiet from 1811 until this date.

1828. May 13, Berne; 20, Dumfries; 22, Soleure.

1834. Aug. 23, Vesuvius; 24, Perthshire; 27, Chichester; also Sept. 21, Oct. 5, and Jan. 12, 1835; same day Tuscany.

1839. May 20, Calabria; 22 and 24, Scotland (Creiff); June 11, Manchester, same day Rome; 12, Manchester.

1842. Jan. 23, Naples and shocks in Comrie; Aug. 26, Calabria; 27, Comrie; Nov. 29, Calabria and Comrie; Dec. 4, Comrie; 5, Naples; 9, Etna; 17, Comrie; 26, Naples.

*II. Synchronism connected with Scandinavian G. C. No.* 1.

1819. Nov. 28, Perthshire; Dec. 3, Norway; 4, Scotland; 17, Norway.

1820. Jan. 20, Norway; 22, Scotland.

1826. Nov. 5, Lunröe (Norway); Arran (Scotland).

*III. Connected with Tatra G. C. No.* 2.

1786. Aug. 11, Newcastle, Lancaster, Whitehaven, Isle of Man, Dublin; 22, Upper Silesia and Moravia.

1821. Oct. 28, Saxony, shocks from S. E. to N. W; 29, Glasgow and Greenock; 30, Saxony.

*IV. Connected with G. C. No.* 4.

1762. Mch. 16, Wexford (Ireland); 20, Shaftesbury, Dorsetshire, England.

1789. Mch. 31, Venice; May 5, Devonshire.

1612. Aug. 11, Switzerland and Shropshire (England).

*V. Connected with G. C. No.* 5.

1671. Sept. 18, English channel, St. Malo, Havre, Calais, Dunkirk, Antwerp.

1692. Sept. 18, Normandy (France), England, Flanders, Holland.

1734. Nov. 5, Sussex, Portsmouth, Chichester, Havre, etc.

A map is added to render the description more intelligible: the solid lines indicate the 5 G. C's above described, and the broken lines represent the radial fissures from Norway, Tatra and Rosa.

*Corollary.* 1. To show, as stated, that a large ratio of the earth's seismic movements are transmitted along the pole of land hemisphere, we may count the total number of shocks in a given term of years, and then see how many pass through Switzerland. Thus counting from Jan. 1650 to 1670, Mallet gives 175 earthquakes as the total on record for that period, of which 73 traverse Switzerland.[12]

2. Attention may be called in connection with the late earthquake which passed Aug. 10, 1884, through New England, New York, Philadelphia, etc., as furnishing additional proof that seismic movements usually follow G. C. This one was transmitted along one of the five equidistant continental trends[13] (which runs from Iceland to Guatemala's volcanoes), passing near the oft-shaken E. Haddam (Conn.), parallel to our Atlantic seaboard, and generally marks, along the base of the Appalachians, the line between the Paleozoic and Mesozoic formations. On the opposite side of the globe it passes near the Caspian "Field of Fire," and the Ullah Bund of the Cutch, and runs between the Paleozoic of the Western Ghauts and the later outflows of the Deccan.

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THE ULTIMATE RESULTS OF CONVERTING THE BASIN OF SAHARA INTO AN INLAND LAKE. By DR. P. H. VAN DER WEYDE, New York, N. Y.

[ABSTRACT.]

CALCULATIONS have been brought forward tending to show that the filling up of such portions of the Desert of Sahara, as are below the ocean level, with sea water, will cause injurious results by inducing a perceptible lowering of the ocean level, and a great disturbance of the terrestrial centre of gravity by withdrawing so much water from the general surface and leading it into the depression now existing. But a careful consideration of the correct

[12] The ratio is, however, much less at some other period, *e. g.*, from 1804–1822, it is only 85 in 1000. For the probable cause of this discrepancy, see my Montreal paper in Proc. A. A. A. S., p. 334.

[13] See Boston Proc. A. A. A. S., p. 439.

figures show that such objections are based upon an overestimate of the amount of water to be displaced, of which, great as it is, the result could only be perceived by the most delicate appliances of the present day and would have no effect of any practical importance.

The results referred to are a slight shifting of the direction of the plumb line around the great circle 90° distant from the Sahara, towards the latter; while the effect would be a slight raise of the level of the Mediterranean, Red Sea and ocean around northern Africa with a corresponding lowering of its level at the antipodes.

There is, however, another consideration which thus far appears to have been overlooked. It is based on the fact that the saltness of the ocean, and of some lakes, is a result of the drainage of the land, out of which the rains continually wash all soluble material, which the rivers carry into them, and where it has to remain, because evaporation can only remove the water. All inland lakes, without outlet to the ocean, are therefore salt, and the degree of this saltness is in certain respects a measure of the amount of soluble material in the watershed which is drained into them. So the salt lake of Utah, which is a saturated solution, shows the abundance of salt in its watershed. It is the same with the Dead Sea, while the Caspian Sea, in which the proportion of salt is much smaller than it is in the ocean, shows that the amount of salt in the basin of the Volga is less than it is in the rest of the earth's solid surface.

The Salt Lake of Utah, as is well known, is the remnant of a large lake which once, at a much higher level, covered a very extensive territory. Notwithstanding the soluble material of its watershed has been mostly washed out, and that at present it receives only supplies of comparatively pure water, the crystallization of salt around its shore is profuse, while the lake is still contracting (of course temporarily only, until the evaporation has become equal to the supply).

The fatal results of admitting salt water upon low lands have often been practically illustrated. So in Egypt the low basin near Alexandria, originally the bed of one of the Nile's outlets, had been drained by evaporation, after damming up the Mediterranean at the north, and the Nile at the southeast. It was once a most fertile region containing a dense agricultural population, until, during one of the wars periodically devastating that much

coveted region, the northern dam was cut for strategical reasons. This gave admission to the salt waters of the Mediterranean and resulted in a concentration of its salt by evaporation, so that after restoring the dam, the soil was found to be charged with such an excess of salt as to be utterly worthless for agricultural purposes; consequently the many villages, once dotting the locality, were never rebuilt, and it is now equivalent to a desert, similar to our bad lands in the west. The reëstablishment of the Nile connection, resulting in a restoration of the original conditions, might redeem this locality.

Experience has shown in Holland (where as well known, the drainage of salt and marshy lakes and gulfs is a specialty) that it takes several years of artificial drainage (consisting in continually pumping out the otherwise accumulating rain water) to wash out the excess of salt, in order to convert the soil into the rich pasture land originally formed by the alluvium of the Rhine, Meuse and Scheld.

With such facts before us, we can easily foresee what the ultimate, unavoidable result will be, when, by the contemplated channel to the Mediterranean, the lower basins of the desert of Sahara have been filled with ocean water. The evaporation being excessively rapid in this arid and rainless region, it will go on at an enormous rate as soon as the depression is filled to almost the ocean level, which, however, it will never reach for reason of the evaporation; this will cause the ocean water to flow continually through the channel to replace the water removed. The result will be a lake of which the saltness will continually increase, and in a few decades reach a point of saturation, when crystallization along its shores will begin, forming a belt of salt around its whole extent.

This belt will rapidly increase in width, so that in a few centuries the original lake will have contracted to its deepest portions, while at last it will disappear, leaving in place an immense deposit of salt. It is not unlikely that the great salt deposits, from which at present rock salt is mined, had a similar origin from natural causes. In fact, the experiment to transform the Sahara Desert into a lake will be the construction of an enormous salt-pan, which may lead to a perceptible reduction of the salt contained in the ocean.

It has been argued that this evaporation would change the climate of the surroundings, and bring rain into thus far rainless localities. This is undoubtedly so, but the amount of rain thus

obtained would never equal the evaporation, and being insufficient, it would only retard, but not prevent the ultimate result described, of a lake in the torrid zone, chiefly supplied with sea-water.

Whether the change of the sandy desert of Sahara into a salt desert is desirable is a question which I leave to others to solve. For my part I do not think that posterity would bless us for such a legacy.

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ON THE RELATIVE LEVEL OF THE ATLANTIC OCEAN AND GULF OF MEXICO, WITH REMARKS ON THE GULF STREAM AND DEEP-SEA TEMPERATURES. By J. E. HILGARD, Superintendent U. S. Coast and Geodetic Survey, Washington, D. C.

[ABSTRACT.]

EXPLANATION of Relief Model, embracing Bay of North America, Gulf of Mexico, and United States east of the Mississippi River, and critical remarks on the same; submergence of the continental outline; fracture of Acadian peninsula extending to submerged continents; estuaries of the Delaware and Chesapeake; sounds of North Carolina.

Basin of the Gulf of Mexico, its barriers and depths; banks of Florida, Louisiana, Yucatan; protrusion of Mississippi delta; temperatures of the water of the Gulf of Mexico near the bottom and on the barriers of inflow.

Depths and temperatures: Are the low deep-sea temperatures due to polar currents, or to maximum density of sea water?

Relative level of the Atlantic and Gulf of Mexico; account of operations conducted by the Coast and Geodetic Survey to ascercertain the precise difference of level between the Atlantic and Pacific Oceans.

Transcontinental line of levels of extreme precision extends from Sandy Hook as far west as middle Missouri; branch to Hampton Roads. Height of bench mark at St. Louis above mean tide at Sandy Hook three feet; comparison of the same with other data. Precise line of levels from Gulf by Mississippi River Commission along the river shows an elevation of the Gulf of Mexico near the mouth of the Mississippi above mean tide at Sandy Hook of about forty inches. More direct line of geodetic levels from Mobile to St. Louis in progress.

Whatever the causes which produce the Gulf Stream, they must effect an elevation of the Gulf above the Atlantic in order to occasion the outflow. That physical fact is here demonstrated by accurate measurement.

Description of Gulf Stream. The North Atlantic trade winds set the waters of the Caribbean Sea against the "Spanish Main" (Central America) which are deflected northward along the coast of Yucatan, and then flow through the straits between Yucatan and Cuba to the Gulf of Mexico, thence through the Florida Straits and Bemini Channel into the Atlantic Ocean, forming what is known as the "Gulf Stream." The part which the Gulf of Mexico has in this, is mainly that of a reservoir or "accumulator," maintaining the outflow at a more uniform rate than the assigned cause would admit of without such a reservoir.

Description of a scheme of observations to be made in order to yield a knowledge of facts leading to a more precise explanation of the Gulf Stream.

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RECENT IMPROVEMENTS IN APPARATUS AND METHODS OF SOUNDING OCEAN DEPTHS. By DANIEL AMMEN, Rear Admiral, U. S. N., Washington, D. C.

[ABSTRACT.]

ON September fifth, 1885, in Philadelphia, at the meeting of the American Association for the Advancement of Science, there was read by the writer, to the geographical section, a paper with the above title, of which the following is an abstract:

More than thirty years ago the intended laying of the Atlantic telegraph cable had awakened a general as well as a special interest in relation to ocean depths and in gaining a knowledge of them, and at that time fair results were obtained in the North Atlantic by Lieutenant Berryman of the navy and others, the depths not being great. A simple and effective method of detaching a sinker, by Lieutenant Brooke, and an improved cup for securing specimens of the bottom, by the late Rear Admiral Sands, were brought into use about that period.

In 1871, Sir William Thomson designed a dynamometer and apparatus for the employment of pianoforte wire for sounding,

with which satisfactory results were obtained in depths of 1,000 fathoms off the coast of Scotland, and later on, in true ocean depths in the Bay of Biscay. The weight of wire was fourteen and one-half pounds per marine mile, which would bear a tension of about 230 pounds. In sounding, a sinker of lead of twenty-seven pounds was used which was hauled up, as usual, in ordinary sounding. His apparatus and wire, compared with any means for deep-sounding then known, were wonderfully light, and have since shown themselves to be all that were requisite for effective work, with some simple modifications made by Captain Belknap, U. S. N., who, on board of the Tuscarora, made a line of soundings from San Diego to the Sandwich islands, and thence to Yokohama, and from the northern end of the Island of Niphon to the Aleutian islands, and thence to Puget sound. He also determined the true continental outline from the last named locality to San Diego, California.

In the execution of this work he took 304 soundings, having a depth of 1,000 fathoms or more; 161 of 2,000 fathoms or more; 38 of 3,000 fathoms or more, and 9 of 4,000 or more. The mean rate of descent for the first thousand fathoms was 10′ 06″; for the second thousand fathoms 11′ 54″; for the third thousand 12′ 46″, and for the fourth thousand 15′ 54″. The reeling in by hand was much slower than now attained by the use of steam, but was satisfactory to a degree when compared with the reeling in of hemp line by whatever means. The deepest sounding made by Belknap and perhaps as ever made, was off the east coast of Japan in 4,655 fathoms, a little more than five and one-quarter statute miles in depth. The thermometer of the best construction known was entirely wrecked by the enormous pressure.

In an official letter when engaged in sounding, Belknap says: "I expect to accomplish all the work with the apparatus of Sir William Thomson which the Department has assigned me, and if I succeed no greater compliment could be paid to the genius of the inventor." Sir William wrote in July, 1874, to the Chief of Bureau of Navigation, under whose instructions the soundings were made; after stating certain difficulties he had encountered in sounding in great depths, he concludes as follows: "I have therefore resolved to alter the apparatus considerably, and am preparing for trials on a new plan which I hope to carry out in five or six days we remain here, and if possible, shall write

you reporting the result." In a reply he was informed specially in relation to the several modifications made by Belknap which enabled him to get satisfactory soundings in depths of 4,000 fathoms. More than a year before, Sir William, when requested, had given kindly assistance toward Belknap's success, and has at various times alluded in the most complimentary manner to the results obtained by Belknap, and his modifications of the apparatus send him.

The employment of this apparatus marked an immense progress in obtaining accurate results, with a great economy of time, labor and cost of apparatus. On page 61 of the Report of the Secretary of the Navy, 1874, will be found a summary of the advantages gained, in the small amount of space and weight required for the apparatus, the large weight of the sinker relatively with the weight of the wire necessary, even in sounding in the greatest depths, and the very little surface friction of the wire in its descent. Miles of wire have very little stretch at ordinary tension, and hemp line a great deal, hence the indications of the dynamometer, in the first case, would be almost instantaneous, and in the second would be obscure and uncertain, as to time and depth when the sinker touched the bottom. Another great advantage was the ease with which the wire was preserved from deterioration.

To appreciate fully the advance made through the use of wire, it is necessary to bear in mind the tons of rope required to reach depths of four or five miles, its rapid deterioration from use, the cumbrous and costly apparatus, the slowness of the process even under the most favorable conditions for sounding, and what is of the greatest import, the uncertainty as to the actual depths obtained, arising from the currents of the ocean carrying great bights of the rope in one or more directions, and from the stretch of hemp line under tension, and its gradual shortening when relieved of the weight of the sinker, relatively light as compared with miles of hemp line, presenting in its descent an immense amount of surface friction.

Belknap used, as a weight in sounding, a bored shot of fifty-five pounds, through which the detachable shaft passed; this weight was entirely satisfactory up to 2,500 fathoms. In deeper water twenty and even thirty pounds of lead were added, all of which were detached on touching the bottom, the shaft, sounding cup and thermometer being the only weights hauled up.

The able Superintendent of the Coast Survey of the United States was not slow in adopting what Belknap had shown to be so admirable. In August, 1874, he began the use of the apparatus of Sir William Thomson, and we find in the soundings executed by Sigsbee, Bartlett and others, a veritable revelation in the contours and depths of our coasts. They have brought to our knowledge the wonderful cleft in the crust of the earth on the line of the Hudson river, extended one hundred miles beyond Sandy Hook, and scarcely less interesting, but not so startling, are the plaster casts of the Gulf of Mexico and of the Caribbean sea. The ocean bed is shown to be more abrupt than the unsubmerged vertical inequalities of the land, and there are substantial reasons why this should be. The depths of the ocean are unvisited by what are popularly called "cloud bursts," from which immense floods are precipitated, which bear millions of tons of debris to lower levels, roughly grading the unsubmerged lands, and indeed beyond, out to the contours of the usually abrupt ocean depths, within which the disintegrating effects of freezing and thawing, and melting snows and mountain torrents are unknown; where volcanic forces assert themselves and raise their pinnacles high in air, the sections beneath the waters sustained laterally by them, and remain almost vertical and undisturbed, save by the lashings of the tempest near the ocean level and at great depths by the slow majestic currents of the sea, that bear their silt and pursue their way, and maintain in part the equilibrium in some of the forces of nature.

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'DEEP-SEA SOUNDINGS IN THE CARIBBEAN SEA. By Comdr. J. R. BARTLETT, U. S. Navy, Washington, D. C.

[ABSTRACT.[1]]

DESCRIPTION of chart showing contour lines, constructed from soundings taken by the U. S. Albatross, Lt. Comdr. Tanner, U. S. N., under the direction of the U. S. Hydrographic Office, Navy Department.

[1] See paper in Science, Jan. 30, 1885, Vol. V, No. 104.

THE PILOT CHART OF THE NORTH ATLANTIC OCEAN. By Comdr. J. R. BARTLETT, U. S. Navy, Washington, D. C.

[ABSTRACT.]

A DESCRIPTION of pilot chart as now issued each month from the U. S. Hydrographic office, showing graphically the weather of the ocean for the coming month, and all information of interest to mariners collected during the month preceding date of issue; also purpose of chart in aiding navigators and in determining the currents of the ocean by drift of wrecks, etc. (The September chart was distributed.)

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## TITLES OF OTHER PAPERS READ IN SECTION E.

ON THE EROSIVE ACTION OF ICE. By Prof. J. S. NEWBERRY, Columbia College, New York, N. Y.

ON SOME LARGE AND PECULIAR FOSSIL FISHES FROM OHIO AND INDIANA. By Prof. J. S. NEWBERRY, Columbia College, New York, N. Y.

ON THE GEOLOGICAL SURVEY OF NEW JERSEY. By Prof. GEORGE H. COOK, State Geologist, New Brunswick, N. J.

SAND BOULDERS IN DRIFT AT COLUMBIA, MO. By Prof. J. W. SPENCER, University of Missouri, Columbia, Mo.

OCCURRENCE OF BOULDERS OF DECOMPOSITION AT WASHINGTON, D. C., AND ELSEWHERE.[1] By Prof. J. W. SPENCER, University of Missouri, Columbia, Mo.

CAUSE OF MOTION IN GLACIERS. By Col. CHARLES WHITTLESEY, Cleveland, O.

NATIVE ANTIMONY FROM YORK, PRINCE WILLIAM CO., NEW BRUNSWICK. By GEORGE F. KUNZ, New York, N. Y.

NOTE ON CASSITERITE FROM KING'S MOUNTAIN, N. C. By Dr. CHARLES W. DABNEY, jr., Raleigh, N. C.

NORTH CAROLINA PHOSPHATES. By Dr. CHARLES W. DABNEY, jr., Raleigh, N. C.

ON THE PHYSICAL CONDITION OF THE INTERIOR OF THE EARTH. By Prof. H. HENNESSY, Brookvale, Donnyhook, Dublin, Ireland.

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA. By CHARLES A. ASHBURNER, Assistant State Geological Survey, Philadelphia, Pa.

[1] Printed in American Naturalist, February, 1885.

DEFLECTION IN THE DIRECTION OF THE ICE-FLOW IN MAINE DURING THE LAST PART OF THE GLACIAL EPOCH. By G. H. STONE, Colorado Springs, Col.

ON TWO SERIES OF KAME OR OSAR GRAVELS WHICH APPEAR TO CROSS EACH OTHER LIKE AN X. By G. H. STONE, Colorado Springs, Col.

ADDITIONAL FACTS CONCERNING THE GLACIAL BOUNDARY IN KENTUCKY, INDIANA AND ILLINOIS. By Rev. G. FREDERICK WRIGHT, Oberlin, O.

EXHIBITION OF A GEOLOGICAL MAP OF THE UNITED STATES, AND A GEOLOGICAL MAP OF NEW YORK, NEW JERSEY, AND PENNSYLVANIA. By Major J. W. POWELL, Director United States Geological Survey, Washington, D. C.

METAMORPHISM IN THE HURONIAN OF THE NORTHWEST. By Prof. R. D. IRVING, Assistant U. S. Geol. Survey, Madison, Wis.

THE SUPPOSED TACONIC FORMATION NEAR PHILADELPHIA. By Prof. H. CARVILL LEWIS, Academy Natural Sciences, Philadelphia, Penn.

THE LIFE AND SCIENTIFIC WORK OF ARNOLD GUYOT. By Prof. WILLIAM LIBBEY, jr., Princeton, N. J.

A BRIEF ACCOUNT OF THE REMARKABLE EXPLORATIONS IN TIBET, MONGOLIA, AND THE FRONTIERS OF INDIA AND CHINA RECENTLY MADE BY KRISHNA, OR A. K., A NATIVE SURVEYOR TRAINED UNDER THE TRIGONOMETRICAL SURVEY OF INDIA. WITH THE OFFICIAL MAP. By TRELAWNEY SAUNDERS, F. R. G. S., India Office, London, Eng.

NEW IDENTIFICATIONS IN BIBLICAL GEOGRAPHY BASED ON THE RECENT SURVEY OF WESTERN PALESTINE MADE FOR THE PALESTINE EXPLORATION FUND. WITH THE GREAT MAP OF THE SURVEY 18 FEET IN LENGTH AND THE REDUCED MAP OF THE OLD TESTAMENT, APOCRYPHA, AND JOSEPHUS, DERIVED THEREFROM. By TRELAWNEY SAUNDERS, F.R.G.S., India Office, London, Eng.

SOME RECENT OBSERVATIONS ABOUT THE CAVES AT THE GIANT'S CAUSEWAY AND IN THE ISLAND OF STAFFA, WITH ESPECIAL REFERENCE TO FINGAL'S CAVE.[1] By F. COPE WHITEHOUSE, New York, N. Y.

[1] This paper was placed upon the programme by the Sectional Committee, but was not read.

SECTION F.

# BIOLOGY.

# ADDRESS

BY

PROFESSOR EDWARD D. COPE,

VICE PRESIDENT, SECTION F.

## *ON CATAGENESIS.*

### I. The Evolution of Organisms.

The general proposition that life has preceded organization in the order of time may be regarded as established. It follows necessarily from the fact which has been derived from palæontological investigation, that the simple forms have, with few sporadic exceptions, preceded the complex in the order of appearance on the earth. The history of the lowest and simplest animals will never be known on account of their perishability; but it is a safe inference from what is known, that the earliest forms of life were the rhizopods, whose organization is not even cellular, and includes no organs whatever. Yet these creatures are alive, and authors familiar with them agree that they display, among their vital qualities, evidences of some degree of sensibility.

The following propositions were laid down by Lamarck, as established by facts known to him, in 1809.[1]

I. "In every animal which has not passed the term of its development, the frequent and sustained employment of an organ, gradually strengthening it, develops and enlarges it, and gives it power proportional to the duration of its use; whilst the constant disuse of a like organ insensibly weakens it, deteriorates it, progressively reduces its functions, and finally causes it to disappear.

II. "All that nature acquires or loses in individuals, through the influence of circumstances to which the race has been exposed

[1] Philosophie Zoölogique, Pt. I, p. 235 (Edit. 1830).

for a long time, either by the predominant use of an organ or by the disuse of such part, she preserves by generation among new individuals which spring from it, provided the acquired changes be common to both sexes or to those which produce new individuals."

The same proposition was previously enunciated by Lamarck in the following condensed form (Recherches sur les corps vivans, p. 50):

"It is not the organ, that is, the nature and form of the parts of the body, which have given origin to its habits and peculiar functions, but it is, on the contrary, its habits, its manner of life, and the circumstances in which individuals from which it came found themselves, which have, after a time, constituted the form of the body, the number and character of its organs, and the functions which it possesses."

Several years ago, not having read Lamarck, I characterized the above hypothesis as the "law of use and effort,"[2] and I have subsequently formulated the *modus operandi* of this law into two propositions. The first of these is, that animal structures have been produced, directly or indirectly, by animal movements, or the doctrine of *kinetogenesis;* the second is, since animal movements are primitively determined by sensibility or consciousness, that consciousness has been, and is, one of the primary factors in the evolution of animal forms. This is the doctrine of *archæsthetism*. The doctrine of kinetogenesis is implied in the speculations of Lamarck in the following language (Philosophie Zoölogique, Ed. 1830, p. 239): "With regard to the circumstances which [nature] uses every day to vary that which she produces, one can say that they are inexhaustible. The principal arise from the influence of climates; from diverse temperatures of the atmosphere and of the environment generally; from diversity of location; from habits, the most ordinary movements, and most frequent actions," etc. The influence of motion on development is involved in Spencer's theory of the origin of vertebræ by strains;[3] and I have maintained the view that the various agencies in producing change mentioned by Lamarck are, in the case of animals, simply stimuli to motion.[4] The immediate mechanical effect of motion

[2] Method of Creation, Proceedings American Philosophical Society, 1871, p. 247.
[3] Principles of Biology, II, p. 195.
[4] On the Relation of Animal Motion to Animal Evolution, American Naturalist, Jan., 1878.

on animal structure has been discussed in papers by Ryder, Hyatt, Clevenger and myself, and I have cited the evidence of vertebrate palæontology as conclusively proving such an effect.[5]

The object of the present paper is to pursue the question of the relation of sensibility to evolution, and to consider some of the consequences which it involves. It is scarcely necessary to observe that in the early stage which the subject presents at the present time, I can only point out the logical conclusions derivable from facts well established rather than any experimental discoveries not already known. And I will say here to those who object to the introduction of metaphysics into biology that they cannot logically exclude the subject. As in one sense a function of nervous tissue, mind is one of the functions of the body. Its phenomena are everywhere present in the animal kingdom. Moreover, when studied in the inductive, *a posteriori* method, metaphysics is an exact science. As Bain observes, it is a good deal easier to foretell the actions of a man than those of the weather. It is only want of familiarity with the subject which can induce a biologist to exclude the science of mind from the field.

For the benefit of those who are not familiar with the doctrine of archæsthetism,[6] I give an outline of its implications. In the first place the hypothesis that consciousness had played a leading part in evolution would seem to be negatived by the well known facts of reflex action, automatism, etc., where acts are often unconsciously performed, and often performed in direct opposition to present stimuli. But while it is well understood that these phenomena are functions of organized structure, it is believed that the habits which they represent were inaugurated through the immediate agency of consciousness. It is not believed that a designed act can have been performed *for the first time*[7] without consciousness on the part of the animal, of the want which the act was designed to relieve or supply. This opinion accords with our knowledge of ourselves, and by irresistible inference, with our belief regarding other animals. From such familiar observation we also know that so soon as a movement of body or mind has

[5] The Evidence for Evolution in the History of the Extinct Mammalia, Am. Assoc. Adv. Sci., 1883, p. 32.

[6] American Naturalist, 1882, p. 454.

[7] The same view is expressed by Ribot, Diseases of the Will, p. 38 (Humboldt Libr.).

been acquired by repetition, consciousness need no longer accompany the act. The act is said to be automatic when performed without exertion, either consciously or unconsciously, and in those functions now removed from the influence of the unconscious mind, such acts are called reflex. The *origin* of the acts is, however, believed to have been in consciousness, not only for the reasons above stated, but also from facts of still wider application. The hypothesis of archæsthetism then maintains that consciousness as well as life preceded organism, and has been the *primum mobile* in the creation of organic structure. This conclusion also flows from a due consideration of the nature of life. I think it possible to show that the true definition of life is, *energy directed by consciousness, or by a mechanism which has originated under the direction of consciousness.* If this be true, the two statements that life has preceded organism, and that consciousness has preceded organism are coëqual expressions.

## II. Consciousness, Energy, and Matter.

Regarding for the time being the phenomena of life as energy primitively determined by consciousness, let us look more closely into the characteristics of this remarkable attribute. That consciousness, and therefore mind, is a property of matter, is a necessary truth, which to some minds seems difficult of acceptance. That it is not an attribute of all kinds of matter is clear enough, but to say that it is not an attribute of any kind of matter is to utter an unthinkable proposition. To my mind the absence of tridimensional matter is synonymous with nothingness or absolute vacuity. To say that phenomena have a material basis is, for me, only another way of saying that they exist. It being granted then that consciousness is an attribute of matter, or a certain behavior of matter, it remains to trace its relation to energy, which is here used in the sense of motion. Consciousness is clearly not one of the known so-called inorganic forces. Objects which are hot, or luminous, or sonorous, are not, as is well known, on that account conscious. Consciousness is not then a necessary condition of energy. On the other hand, in order to be conscious, bodies must possess a suitable temperature, and must be suitably nourished. So energy is a necessary condition of consciousness. For this reason some thinkers regard conscious-

ness as a form or species of energy. For my own part, in classification, I prefer to keep very different things apart. To classify consciousness with heat, light, sound, etc., does violence to my sense of fitness and to all proper definitions. When a form of energy is developed (as heat, light, etc) which was not present before, we know, in accordance with the law of the conservation of energy, that the energy was already present in some other form. We thus get something from something. We cannot hold the same view when consciousness appears where it had not been before. It is like the attempt to add beans and potatoes to get apples, etc.; in a word it is an attempt to get something out of nothing. To look upon it as a *product* of the metamorphosis of energy, is like regarding a man as the product of the door which is opened in order to conduct him to sight. None but a savage could entertain such an opinion.[8]

This is well shown by Professor Clifford in the following passage; "It will be found excellent practice in the mental operations required by this doctrine, to imagine a train the forepart of which is an engine and three carriages linked with iron couplings, and the hind part three other carriages linked with iron couplings; the bond between the two parts being made out of the sentiments of amity subsisting between the stoker and the guard."[9] This satire, whether intentionally or not on the part of its learned author, expresses at once the distinctive character of consciousness *in esse* and the impossibility of dissociating it from energy *in posse*. For it is sufficiently clear that while the conscious feelings of the stoker and the guard could *by themselves* do nothing for the train, such a state is essential to the energy displayed by them when they are at work for its benefit. We all understand the absurdity of such expressions as the equivalency of force and matter, or the conversion of matter into force. They are not, however,

[8] In view of the nature of the case, as well as of the truths of Kinetogenesis and archæsthetism, it is much more logical to believe that the consciousness is derived from an outside source, and is communicated to matter which is in a proper energetic state. The difficulties in the way of this view are largely diminished by a consideration of the well known facts of *discontinuous consciousness*. There is a form of brain malady in which persons, whose consciousness is clearly continuous to outside observers, lead two or more distinct conscious lives, the one of which knows nothing about the other. This is caused by the *abolition of the memory* of a part of the conscious existence. Now it is far more probable than not, that in a transfer of consciousness from one physical basis to another, the molecular structure which is the condition of memory should be lost in whole or in part.

[9] Scientific Basis of Morals, Humboldt Library Ed., p. 21.

more absurd than the corresponding proposition more frequently heard, that consciousness can be converted into energy, and *vice versa*.

The energetic side of consciousness, however, may be readily perceived by a little attention to its operations. Acts performed in consciousness involve a greater expenditure of energy than the *same acts* unconsciously performed. The difficulty of a given piece of labor is in direct proportion to its novelty; that is, is in direct proportion to the amount of endeavor we use in its performance. This is another way of saying that the labor is directly as the consciousness involved. Another evidence of the dynamic character of consciousness is its exclusive and therefore complementary character. Two opposite emotions cannot occupy the mind at the same moment of time. An emotion excludes all high intellectual work, and *vice versa*.

But there is no fact with which we are more familiar than that consciousness in some way determines the direction of the energy which it characterizes. The stimuli which affect the movements of animals at first only produce their results by transmission through the intermediation of consciousness. Without consciousness, education, habits, and designed movements, would be impossible. So far as we know, the instinct of hunger, which is at the foundation of animal being, is a state of consciousness in all animals. This incontestable fact is overlooked by the materialists properly so called.

On the other hand, as consciousness is an attribute of matter, it is of course subject to the laws of necessity to which matter and energy conform. For instance, it cannot cause two solid bodies to occupy the same space at the same time, nor can it add one body to one body and thus make three bodies. No more can it make ten foot pounds of energy out of five foot pounds of energy, and it cannot abolish time more than it can annihilate space. These are fundamental truths which are overlooked by a majority of mankind. Moreover, nothing is more common than to hear life or mind spoken of as though it of itself is a "substance," and not as it should be as an *attribute* or condition of substance or matter.

What is then the immediate action of consciousness in directing energy into one channel rather than another? To take an illustration: Why, from a purely mechanical point of view, is the

adductor muscle of the right side of the horse's tail contracted to brush away the stinging fly from the right side of the horse's body rather than the left adductor muscle? Why was the contraction-provoking energy deflected into the right interspinal motor nerves rather than into those of the left side? Why is the ear of the horse turned forward to catch the sound in front of him and backwards to gather the sound coming from behind? The first crude thought is, that consciousness supplies another energy which turns aside the course of the energy required to produce the muscular contraction; either as the man with the rein in his hand turns aside the horse's head, or as the shield he holds deflects a moving body. But consciousness, *per se*, that is, regarding it in its proper and distinctive definition, is not itself a force (= energy). How then can it exercise energy? Certainly no more than the bare goodwill of the train hands can pull the train. Such an explanation is to admit the possibility of making something out of nothing.

### III. The Retrograde Metamorphosis of Energy.

The key to many weighty and mysterious phenomena lies in the explanation of the so-called voluntary movements of animals, I say "so-called," because true will is not at all involved in the question. I mean the acts directed by consciousness, the acts which would not take place at all if the animal were unconscious. That there are many such acts you well know. The explanation can only be found in a simple acceptance of the fact as it is, in the thesis, that *energy can be conscious*. If true, this is an ultimate fact, neither more nor less difficult to comprehend than the nature of energy or matter in their ultimate analyses. But how is such an hypothesis to be reconciled with the facts of nature, where consciousness plays a part so infinitesimally small? The explanation lies close at hand, and has already been referred to. *Energy become automatic is no longer conscious*, or is about to become unconscious. That this is the case is matter of every-day observation on ourselves and on other animals. What the molecular conditions of consciousness are, is one of the problems of the future, and for us a very interesting one. One thing is certain, the organization of the mechanism of habits is its enemy. *It is clear that in animals, energy, on the loss of conscious-*

*ness, undergoes a retrograde metamorphosis;* as a lower form of energy, does later in the history of organized beings on their death. This loss of consciousness is first succeeded by the so-called involuntary and automatic functions of animals. According to the law of catagenesis, the vegetative and other vital functions of animals and plants are a later product of the retrograde metamorphosis of energy. With death, energy falls to the level of the polar tensions of chemism, and the regular and symmetrical movements of molecules in the crystallization of its inorganic products. Let us now trace in more detail the energies displayed by animals and plants.

It has been already advanced (see page 458) that the phenomena of growth-force, which are especially characteristic of living things, originated in the direction given to nutrition by consciousness, and by the automatic movements derived from it. There remain, however, some other phenomena which do not yield so readily to this analysis. These are: first, the conversion by animals of dead into living protoplasm; second, the conversion of inorganic substances into protoplasm by plants; and third, the manufacture of the so-called organic compounds from the inorganic by plants. To these points we may return again. It is also well known that living animal organisms act as producers, by conversion, of various kinds of inorganic energy, as heat, light, sound, electricity, motion, etc. It is the uses to which these forces are put by the animal organism, the evident design in the occasion of their production, that gives them the stamp of organic life. We recognize the specific utility of the secretions of the glands, the appropriate distribution of the products of digestion, and adaptation of muscular motion to many uses. The increase of heat to protect against depression of temperature; the light to direct the sexes to each other; the electricity as a defence against enemies; display unmistakably the same utility. We must not only believe that these functions of animals were originally used by them, under stimulus, for their benefit, but if life preceded organism, that the molar mechanism which does the work, has developed as the result of the animal's exertions under stimuli. This will especially apply to the mechanism for the production of motion and sound. Heat, light, chemism and electricity doubtless result from molecular aptitudes inherent in the constitution of protoplasm. But the first and last production of even these

phenomena is dependent on the motions of the animal in obtaining and assimilating nutrition. For without nutrition all energy would speedily cease. Now the motion required for the obtaining of nutrition has its origin in the sensation of hunger. So even for the first steps necessary to the production of inorganic forces in animals, we are brought back to a primitive consciousness.

To regard consciousness as the primitive condition of energy, contemplates an order of evolution in large degree the reverse of the one which is ordinarily entertained. The usual view is, that life is a derivative from inorganic energies as a result of high or complex molecular organization, and that consciousness (= sensibility) is the ultimate outcome of the nervous or equivalent energy possessed by living bodies. The failure of the attempts to demonstrate spontaneous generation will prove, if continued, fatal to this theory. Nevertheless the order cannot be absolutely reversed. Such a proceeding is negatived by the facts of the necessary dependence of the animal kingdom on the vegetable, and the vegetable on the inorganic for nutrition, and consequently for existence. So the animal organism could not have existed prior to the vegetable, nor the vegetable prior to the mineral. The explanation is found in the wide application of the "doctrine of the unspecialized,"[10] so clearly demonstrated by palæontology. From this point of view creation consists in specialization, an expression which describes the specific action of the general principle described by Spencer as the conversion of the homogeneous into the heterogeneous. To be more explicit, it consists of the production of mechanism out of no mechanism, of different kinds of energy out of one kind of energy. The material basis of consciousness must then be a generalized substance which does not display the more automatic and the polar forms of energy. From a physical standpoint protoplasm is such a substance. Its instability indicates weakness of chemical energy also, which suggests that the complexity of its molecule may be due to some form of energy not properly chemical. The readiness with which it undergoes retrograde metamorphosis shows that it is not self-sustaining, and furnishes a good illustration of creation of specialized substances by a running down in the scale

[10]The term specialized, introduced into biology by Professor Dana, has been used in connection with energy in creation by the author, *Penn Monthly*, 1875, p. 509.

of being. Loew and Bokorny[11] suggest that "the cause of the living movements in protoplasm is to be sought for in the intense atomic movements, and therefore easy metamorphosis of its aldehyde groups of components;" the molecular movements becoming molar, to use the language of Lester Ward. The position which I now present requires the reversal of the relations of these phenomena. Generalized matter must be supposed to be capable of more varied molecular movements than specialized matter, and it is believed that the most intense of all such movements are those of brain tissue in mental action, which are furthest removed of all from molar movements. From this point of of view, when molar movements are derived from molecular movements, it is by a process of running down of energy, not of elevation; by an increase of the distance from mental energy, not an approximation to it.

The fact that the physical basis of consciousness is composed of four substances, which are respectively a monad, a dyad, a triad and a tetrad, doubtless has something to do, as I have suggested,[12] with its exhibition of this remarkable attribute. It might be supposed that the presence of carbon had the effect of restraining the chemical and physical molecular tendencies of the three other substances. From this standing-ground we may imagine that other substances besides protoplasm might support consciousness and life. In other parts of the universe, other substances they would have to be, if consciousness exist there.

The manner in which protoplasm is made at the present time is highly suggestive. It is manufactured by living plants out of inorganic matter, the hydrogen, carbon, nitrogen and oxygen contained in the atmosphere and in the earth. As dead plants will not perform this function, this action is regarded as in some way due to the presence of life. The energy peculiar to living protoplasm, and derived primarily in part only from the sun's rays, directs energy so that the complex molecular aggregation protoplasm is the result. This is the only known method of manufacture from inorganic matter, of this substance. The first piece of protoplasm had however no paternal protoplasm from which to derive its being. The protoplasm-producing energy must, there-

[11] Die Chemische Kraftquelle in Lebenden Protoplasma, von O. Loew u. T. Bokorny, Munich, 1882, 1.

[12] *Penn Monthly*, 1876, *p.* 574.

fore, have previously existed in some form of matter not protoplasm. This is also suggested by the fact that it really antagonizes the chemical forces, and might be called, from this fact, *antichemism*. The protoplasm-sustaining energy of animal protoplasm may be a less energetic derivative, or *vice versa*. In terms of the theory of catagenesis, the plant life is a derivative of the primitive life, and it has retained enough of the primitive quality of self-maintenance to prevent it from running down into forms of energy which are below the life level; that is, such as are of the inorganic chemical type, or the crystalline physical type. A part of the energy does so run down, as can be seen in the few automatic movements of plants, and the phosphorescence of some. Also symmetrical crystals are made by some. But M. Pasteur has shown[13] that whenever the crystals are of the organic type, *i. e.*, contain carbon, they are not symmetrical but are unilateral, or, as he terms them, dissymmetrical. This indicates that the presence of carbon has restrained, a little, the absolute symmetrical automatism of the formative force.

## IV. Origin of Life on the Earth.

If then some form of matter other than protoplasm has been capable of sustaining the essential energy of life, it remains for future research to detect it, and to ascertain whether it has long existed as part of the earth's material substance or not. The heat of the earlier stages of our planet may have forbidden its presence, or it may not. If it were excluded from the earth in its first stages we may recognize the validity of Sir William Thomson's suggestion that the physical basis of life may have reached us from some other region of the cosmos by transportation on a meteorite. If protoplasm in any form were essential to the introduction of life on our planet, this hypothesis becomes a necessary truth. Here let me refer to the fact that hydrocarbonaceous substances have been discovered in meteorites. Here also the remarkable discovery of Huggins claims attention.[14] This veteran spectroscopist has detected the lines of some hydrocarbon vapor in the spectra of interplanetary spaces. The signifi-

[13] *Revue Scientifique*, Jan., 1884, p. 2.

[14] See address of C. W. Siemens, Pres. British Assoc. Adv. Science, 1882; *Nature*, 1882, p. 400.

cance of this discovery is at once perceived if we believe that hydrocarbons are only produced under the direction of life.[15]

Granting the existence of living protoplasm on the earth, there is little doubt that we have some of its earliest forms still with us. From these simplest of living beings both vegetable and animal kingdoms have been derived. But how was the distinction between the two lines of development, now so widely divergent, originally produced? The process is not difficult to imagine. The original plastid dissolved the salts of the earth and appropriated the gases of the atmosphere and built for itself more protoplasm. Its energy was sufficient to overcome the chemism that binds the molecules of nitrogen and hydrogen in ammonia, and of carbon and oxygen in carbonic dioxide. It apparently communicated to these molecules its own method of being, and raised the type of energy from the polar non-vital to the adaptive vital by the process. Thus it transformed the dead mineral world, perhaps by a process of invasion, as when a fire communicates itself from burning to not burning combustible material. Thus it has been doing ever since, but it has redeposited some of its gathered stores in various non-vital forms. Some of these are in organic forms, as cellulose; others are crystals imprisoned in its cells; while others are amorphous, as waxes, resins and oils. But consciousness apparently early abandoned the vegetable line. Doubtless all the energies of vegetable protoplasm soon became automatic. The plants in general, in the persons of their protist ancestors, soon left a free-swimming life and became sessile. Their lives thus became parasitic, more automatic, and in one sense degenerate.

The animal line may have originated in this wise. Some individual protists, perhaps accidentally, devoured some of their fellows. The easy nutrition which ensued was probably pleasurable, and once enjoyed was repeated, and soon became a habit. The excess of energy thus saved from the laborious process of making protoplasm was available as the vehicle of an extended

[15] Says Mr. S. F. Peckham (*American Journal of Science and Arts*, 1884, p. 105) on the origin of bitumens: "These chemical theories [of the origin of bitumen] are supported by great names, and are based upon very elaborate researches, but they require the assumption of operations nowhere witnessed in nature or known to technology. . . In the chemical processes of nature complex organic compounds pass to simpler forms, of which operation marsh gas, like asphaltum, is a resultant and never the crude material upon which decomposing forces act."

consciousness. From that day to this, consciousness has abandoned few if any members of the animal kingdom. In many of them it has specialized into more or less mind. Organization to subserve its needs has achieved a multifarious development. There is abundant evidence to show that the permanent and the successful forms have ever been those in which motion and sensibility have been preserved, and most highly developed.

The review of the history of living organisms has been epitomized in the following language:[16] "Evolution of living types is then a succession of elevation of platforms, on which succeeding ones have built. The history of one horizon of life is that its own completion but prepares the way for a higher one, furnishing the latter with conditions of a still further development. Thus the vegetable kingdom died, so to speak, that the animal kingdom might live, having descended from an animal stage to subserve the function of food for animals. The successive types of animals first stimulated the development of the most susceptible to the conflict, in the struggle for existence, and afterwards furnished them with food."

## V. Catagenesis of Inorganic Energy.

If the principles adopted in the preceding pages be true, it is highly probable that *all forms* of energy have originated in the process of running down or specialization from the primitive energy.

In the department of physics I am not at home, and touch upon it merely to carry out to a necessary conclusion the hypothesis presented in the preceding pages. It may be that physicists and chemists may find value in the suggestions which come from the side of biology. A cursory perusal of the general hypotheses current in these departments shows that the door is wide open to receive light from this quarter. What can be offered here is of the vaguest, yet it may suggest thought and research in some minds.

In the first place it is highly probable that one of the problems to be solved by the physicists of the present and future, is that of a true genealogy of the different kinds of energy. In this connection a leading question will be the determination of the essen-

[16] American Naturalist, 1880, p. 266.

tial differences between the different forms of energy, and the material conditions which cause the metamorphosis of one kind of energy into another.

In constructing a genealogy of energies, it must be observed that we shall probably obtain, not a single line of succession, but several lines of varying lengths. It must also be remembered, that as in forms of the material world which are their expression, a greater or less extensive exhibition of all the types remains to the present day.

That the tendency of purely inorganic energy is to "run down," in all except possibly some electric operations, is well known, Inorganic chemical activity constantly tends to make simpler compounds out of the more complex, and to end in a satisfaction of affinities which cannot be further disturbed except by access of additional energy. In chemical reaction the preference of energy is to create solid precipitates. In the field of the physical forces we are met by the same phenomenon of running down. All inorganic energies or modes of motion tend to be ultimately converted into heat, and heat is being steadily dissipated into space. Therefore the result has been and will be the creation of the mineral kingdom; of the rocks and fluids that constitute the masses of the worlds.

The process of creation by the retrograde metamorphosis of energy, or what is the same thing, by the specialization of energy, may be called *catagenesis*. It may be denied, however, that this process results in a specialization of energy. The vital energies are often regarded as the most special, and the inorganic as the most simple. If we regard them, however, solely in the light of the essential nature of energy, *i. e.*, power, we must see that the chemical and physical forces are most specialized. The range of each species is absolutely limited to one kind of effect, and their diversity from each other is total. How different this from the versatility of the vital energy! It seems to dominate all forms of conversion of energy, by the mechanisms which it has, by evolution, constructed. Thus, if the inorganic forces are the products of a primitive condition of energy which had the essential characteristics of vital energy, it has been by a process of specialization. As we have seen, it is this specialization which is everywhere inconsistent with life.

With these preliminary remarks we may now consider very

tentatively the relations of the different kinds of energy to each other and to consciousness. In practice it is sometimes difficult to draw the line between conscious and unconscious states of energy. One reason is, that although a given form of energy may be unconscious, consciousness may apprehend the action by perceiving its results. The distinction is rendered clearer by the reflection that we can perceive by sight or touch any action of the body of whatever character. The energy of the conscious type is therefore altogether mental. The relations may be expressed as follows:

| A. Designed (always molecular). | *Examples.* |
|---|---|
| I. Conscious. | |
| 1. Involving effort | "Voluntary" acts. |
| 2. Not involving effort | Passive perception. / Conscious automatism. |
| II. Unconscious. | |
| 3. Involving mental process | Unconscious automatic. |
| 4. Not involving mental process | Reflex. |
| B. Not designed. | |
| I. Molecular. | |
| 5. Electric, / 6. Chemical, / 7. Physical, | Crystallific and non-crystallific. |
| II. Molar. | |
| 8. Cosmic. | |

The only strictly molar energies of the above list are the cosmical movements of the heavenly bodies. The others are molecular, although they give rise to molar movements, as those of the muscles, of magnetism, etc. Some molar movements of organic beings, are not, *in their last phases*, designed; as those produced by nervous diseases.

The transition between the organic and the inorganic energies may be possibly found in the electric group. Its influence on life, its production of contractions in protoplasm, and its resemblance to nerve force are well known. It also compels chemical unions otherwise impracticable, thus resembling the energy of the protoplasm of plants, whose energy in actively resisting the disintegrating inorganic forces of nature is so well known. Perhaps this type of force is an early-born of the primitive energy, one which has not descended so far in the scale as the chemism, which holds so large a part of nature in the embrace of death.

Vibration is inseparable from our ideas of motion or energy, not excluding conscious energy. There are reasons for supposing

that in the latter type of activity the vibrations are the most rapid of all those characteristic of the forces. A center of such vibrations in generalized matter would radiate them in all directions. With radiant divergence the wave lengths would become longer, and their rate of movement slower. In the differing rates of vibrations we may trace not only the different forms of energy, but diverse results in material aggregations. Such may have been the origin of the specialization of energy and of matter which we behold in nature.

Such thoughts arise unbidden as a remote but still a legitimate induction, from a study of the wonderful phenomenon of animal motion; a phenomenon everywhere present, yet one which retreats, as we pursue it, into the dimness of the origin of things. And when we follow it to its fountain head, we seem to have reached the origin of all energy, and it turns upon us, the king and master of the worlds.

# PAPERS READ.

THE RELATIONS BETWEEN THE THEROMORPHOUS REPTILES AND THE MONOTREME MAMMALIA. By Prof. E. D. COPE, Philadelphia, Pa.

THE Theromorpha are that order of Reptilia in which the quadrate bone is fixed, and the ribs are two-headed; where the precoracoid bone is present and the coracoid bone is of reduced size, and is free at the extremity; and where the vertebral centra are deeply biconcave; where the pubis is entirely anterior to the ischium, and is united with it without intervening obturator foramen. In this order there are two divisions; first, Anomodontia, where there are several sacral vertebræ, and the vertebræ are not notochordal; and second, the Pelycosauria, where the vertebræ are notochordal, and there are only two or three sacral vertebræ. It is with the latter sub-order that the present paper has to do. Its species are so far only known from the beds of the Permian epoch. They constitute moreover the only reptiles of that epoch, for it is not until the following or Triassic period that the orders which characterize Mesozoic time, make their appearance. In the Permian epoch then, there are no crocodiles nor Ichthyosaurs nor Plesiosaurs nor Dinosaurs, to say nothing of orders that appeared still later.

THE STRUCTURE OF THE COLUMELLA AURIS IN CLEPSYDROPS LEPTOCEPHALUS.— As already briefly described by me, this element is bifurcate at the proximal extremity. The shorter expanded extremity is the stapes proper. The oblique perforation of its base is a character which has not been hitherto observed in any reptile, not even in the allied form Hatteria (Huxley). If, as is probable, the perforation is homologous with the foramen of the mammalian stapes, we have here a distinct point of resemblance to this class. The longer proximal branch of the columella has only half the width of the stapedial portion, and its long axis makes an obtuse angle with that of the latter. It is perhaps the incus, but for the present I call it the epicolumella. Huxley remarks[1] that in a

[1] Proceedings Zool. Society, London, 1869, p. 391.

young Mammalian fœtus "it appears exactly as if the incus were the proximal end of the cartilage of the first visceral arch." The columella now described resembles a rib, of which the epicolumellar process resembles the head, and the stapes the tubercle. If this process be the incus, the stapes is shortened as in the majority of Mammalia, unless the primitive suture between the two be longitudinal. The form and position of the true stapes give support to the view of Salensky, that it is not part of a true visceral arch, but is developed in the connective tissue surrounding the mandibular artery. We see that in this Pelycosaurian it is not the proximal part of the arch, and that it surrounds the mandibular artery. The columella is divided into at least two distinct elements. This is clearly indicated by its abrupt truncation distally by a rough sutural surface. If there is but one bone distad to the stapes, it is homologous with the cartilage, which has been shown by Peters[2] to be distinct in Hatteria, crocodiles and various lizards. It is the triangular ligament of Cuvier. If the epicolumella be incus, this element is malleus; and it is usually identified as such by the older anatomists. In this structure we have evidence that the hypothesis that the articular and quadrate bones are homologous with the ossicula auditus is incorrect. The Pelycosauria will probably come under the division observed by Dollo, and called "Sauropsides malleoferes" of Albrecht. We have here an especial approximation to the Mammalia in two points: (1) The perforation of the head of the stapes; (2) and the ossification of the incus, which is distinct from the malleus, thus furnishing homologues of the principal ossicles of the ear. It is unnecessary to observe however, that this part of the skeleton does not resemble the corresponding part in the known Monotremes.

STRUCTURE OF THE QUADRATE BONE IN THE GENUS CLEPSYDROPS.—The quadrate bone in *Clepsydrops leptocephalus* Cope, already described, is of highly interesting form. It consists of two portions, a vertical and a transverse, the latter much longer than the former. The vertical portion is wedge-shaped, with the base fashioned into the condyle for the mandibular ramus. Its posterior face to the apex is articulated with the large squamosal, which rises toward the parietal bone. The distal part of the quadrate is vertically grooved anteriorly, and each edge sends a process forwards. The internal is short, and articulates with the ptery-

[2]Monatsberichte der Akademie Wissenchaften, Berlin 1868 (p. 592) — 1870.

goid. The external is the long horizontal part of the bone already mentioned. It is compressed and at the end is acuminate. Although the malar bone is out of place in the specimen described, examination of the skull of the *Clepsydrops natalis*, where it is preserved in position, shows that this horizontal ramus of the quadrate is nothing more than the zygomatic process of the squamosal bone of the Mammalia, forming with the malar bone the zygomatic arch. *In the Pelycosauria there is but one posterior lateral arch*, as is demonstrated by many specimens; hence, we have here a reptile with a zygomatic arch attached to the distal extremity of the quadrate bone.

Important results follow this determination. We have seen that, with Peters, we need no longer look to the auricular chain of ossicles, and especially to the incus, to find the homologue of the os quadratum of the Vertebrata below the Mammalia. According to Albrecht *the os quadratum is the homologue of the zygomatic portion of the squamosal bone.* If this be true, in the process of specialization of the reptiles, the anterior or zygomatic portion of the quadrate has been lost or separated as a quadratojugal bone, and the condylar portion extended, until it has reached the extreme length we observe in snakes. This determination of the character of the quadrate bone in the theromorphous Reptilia is confirmatory of the theory broached by Albrecht.[3] Among many propositions novel to the science of osteology, none has been more unexpected than his assertion that the quadrate bone is the homologue of the zygomatic and glenoid portion of the squamosal bone of Mammalia. This is in contradiction to the view held by many comparative anatomists from the day of Reichert to the present time.

I made a study of these arches several years ago, which is published in the Proc. A. A. A. S., Vol xix, 1870. Accepting the prevailing view that the quadrate bone is one of the auditory ossicles, I naturally homologized the superior arch of the reptilian skull, which articulates with the squamosal proper, with the zygomatic arch, and looked upon the quadratojugal arch as an additional structure, connected with the peculiar development of the supposed incus. Should Albrecht's determination of the homology of the quadrate bone prove to be correct, the quadratojugal arch

[3]Sur la valeur morphologique de l'articulation mandibulaire et des osselets de l'oreille, etc., Bruxelles. Mayolez, 1883.

is the zygomatic, and the superior arch becomes the accessory one. This being admitted, the Lacertilia cannot be said to have a zygomatic arch, and the Theromorpha do not possess their postorbitosquamosal arch; the diversity between the two orders being thus greater than has been supposed.

THE ARTICULATION OF THE RIBS IN EMBOLOPHORUS.—The ribs of the Theromorpha are two-headed. While the tubercular articulation has the usual position at the extremity of the diapophysis, the capitular is not distinctly, or is but partially indicated, on the anterior edge of the centrum, in Clepsydrops and Dimetrodon. In Embolophorus, as I showed in 1869, the capitular articulation is distinctly to the intercentrum. A second and larger species of that genus, recently come to hand, displays this character in a striking degree, since the intercentrum possesses on each side a short process with a concave articular facet for the head of the ribs. From the slight corresponding contact with the intercentrum seen in Dimetrodon and other genera, there can be little doubt that this is the true homology of the ribs in the order Theromorpha. The consequence follows from this determination, that the ribs of this order are intercentral and not central elements, and that they do not therefore belong to the true vertebræ, thus agreeing with the chevron bones, with which they are homologous.

It is also true that this type of rib-articulation *approximates closely that of the Mammalia*, where the capitular articulation is in a fossa excavated from two adjacent vertebræ. This is what would result if the intercentrum were removed from a Theromorph reptile, and the head of the rib allowed to rest in the fissure between the centra left by the removal. It is well known that the double rib articulation of the other reptilian orders which possess it, viz.: Ichthyopterygia, Crocodilia, Dinosauria and Pterosauria, and in the birds, is different, the capitular connection being below the tubercular, on the centrum. Whether the capitular articulations and the ribs in these orders are homologous with those of the Theromorpha, remains to be ascertained.

THE POSTERIOR FOOT IN PELYCOSAURIA.—The foot-bones of the reptiles of the suborder Pelycosauria are abundant in the collections from the Permian formation, and I have examined my collection for specimens in which they are in normal connection, for the purpose of identifying them. I have been so fortunate as to find an entire tarsus, with the proximal parts of the metatarsi, in

the skeleton which served as the type of my description of *Clepsydrops natalis*.[4] The characters presented by this foot are no doubt present in all of the Clepsydropidæ, which includes the genera Theropleura, Dimetrodon, Embolophorus, and probably others. Tarsal bones identical with those of the *C. natalis* were found with the original specimens of *C. collettii*, and others of much larger size, accompany remains of species of Dimetrodon, or Embolophorus.

The astragalus and calcaneum are large and well specialized bones, distinct from each other and from the other tarsal elements. They do not resemble the corresponding bones of any known type of vertebrate, as will presently appear. The navicular bone is distinct, and the cuboid apparently consists of a single element. This depends on the interpretation given to a small bone on its posterior face, which is broken on its free edge, and may be the head of the fifth metatarsus. There are three elements in contact with the distal face of the navicular, which correspond with the three mammalian cuneiforms. The space available for this contact seems hardly sufficient for the three elements present, one of which is out of position and on the inferior side of the carpus. This element looks also from its free inferior side like an ungual phalange, but is flatter than is characteristic of this family. There are three metatarsals distal to the navicular, which are well accommodated with articular facets on the distal extremities of the three bones in question, so that their identification as the three cuneiforms is probably necessary. The two remaining metatarsals are articulated, the fourth to the exterodistal facet of the cuboid; and the fifth to the exterior side of the cuboid. The third, fourth and fifth metatarsals are directed at an obtuse angle posteriorly from the long axis of the astragalus.

This structure is more mammalian than any form of foot yet known among reptiles, and agrees with the indications of mammalian character described as existing in the long bones of the limbs by Owen and by myself.

The astragalus is an oblong bone with one long straight side, viz., that which is in contact with the calcaneum. This side has two facets for articulation with the calcaneum, which are separated by a groove, which forms a foramen when the two bones are in

[4] Proceedings American Philosoph. Society, 1879, 509.

place. The proximal extremity of the bone is much smaller than the distal, and is subround. The proximal half of the bone would be nearly cylindric were it not for the truncation caused by the calcaneal facet. The distal half of the bone is robust, and is surrounded on all sides by facets. These are the external or calcaneal, the distal or navicular, and the internal which is larger than the other two together. The first two are oblong and truncate, the navicular twice as large as the calcaneal, its transverse much exceeding its anteroposterior diameter. The internal facet, already mentioned, covers the internal face of the distal half of the astragalus, which projects further inwards than the proximal half, rising abruptly from it. The facet is continuous with the navicular, and is at right angles to its plane. It widens proximally, and its proximal border is deeply notched. Its surface is convex from back to front, but not strongly so. In the astragalus of a species of Dimetrodon, it is divided by an angle into two facets, the two faces thus produced being nearly at right angles to each other. This inferior part of the facet is continued into a prominent border which is more or less roughened. A rounded tuberosity of the inferior face of the bone occupies the space between this border and the calcaneal border, so approaching the notch already described, as to cause a groove to proceed from it posteriorly and inwards. I described the corresponding bone in the *Clepsydrops collettii* (Proceeds. Phila. Academy, 1875, p. 409) as a possible coracoid.

The calcaneum has its postero-external edge broken in the specimen of *Clepsydrops natalis* described, but it is probably a semidiscoid bone, with its straight margin applied to the astragalus. This margin presents a median flat elongate-oval facet, which is separated by grooves from a facet at each end of the inner side. The proximal facet is the narrower, and passes by a curve into the proximal extremital facet, which is adjacent to the corresponding proximal facet of the astragalus. The distal internal facet is triangular and wider than long, and is separated by an angle only from the distal facet. The latter is a little more than a half circle in outline, and joins one bone of the second row, which I suppose to be the cuboid. The fact that it does not articulate with the second element in that row leads me to suspect that the latter is the head of a fifth metatarsal. The external edge of the bone thins out more rapidly at the distal than at the proximal extremity.

The cuboid bone is pentagonal in outline, and square in transverse section. It is not unlike that of the Amblypodous Mammalia. It has a transverse proximal facet, and two distal ones which meet at an angle about right. The fifth metatarsal is articulated with its posterior face; and the fourth with the exterior distal face. The ectocuneiform articulates with the interior distal face. The navicular bone is subtriangular in transverse section, and with a subquadrate base articulating with the cuboid. Its longitudinal and anteroposterior diameters are about equal. The distal or metatarsal articulation of the entocuneiform is transverse and flat.

The manner of articulation of the ankle-joint must have been different from the usual reptilian type. The proximal extremities of the astragalus and calcaneum combined are not too large to have received the distal extremity of the fibula, so that the tibial articulation must be sought elsewhere. This may have been on the large distal facet of the anterior or inner face of the bone. A part of this facet looks upwards and probably supported the tibia, which was thus removed by a short space from that of the fibula. The down-looking part of the facet, which is more distinct in Embolophorus, must have articulated with a separate element. This may have been a spur, such as exists in the known genera of the Monotremata; as the position is identical with that which bears this appendage in those animals. It is quite evident that an element additional to those known in the ordinary reptilian foot exists in the Clepsydropidæ.

The separation of the distal extremities of the tibia and fibula is not usual among reptiles, but it is common in the salamanders, where the os intermedium comes between them. It is also evident that the subcylindric proximal part of the astragalus, which intervenes between the supposed tibial and fibular articulations, represents that bone.

The metatarsals are directed obliquely backwards as well as outwards, as in Tachyglossus and Platypus.

The following results may be derived from the preceding statements: (1) The relations and number of the bones of the posterior foot are those of the Mammalia much more than those of the Reptilia. (2) The relations of the astragalus and calcaneum to each other are as in the Monotreme *Platypus anatinus*. (3)

The articulation of the fibula with both calcaneum and astragalus is as in the Monotreme order of mammals. (4) The separate articulation of the anterior part of the astragalus with the tibia is as in the same order. (5) The presence of a facet for an articulation of a spur is as in the same order.[5] (6) The posterior-exterior direction of the digits is as in the known species of Monotremata.

Thus the characters of the posterior foot of the Pelycosauria confirm the evidences of Monotreme affinity observed by Professor Owen and myself in the bones of the legs, especially of the anterior leg. It remains a fact that with this resemblance in the leg there is a general adherence to the reptilian type in the structure of the skull. But this adherence is not so exclusive as has been supposed, as I have endeavored to show.

THE ORIGIN OF THE MAMMALIA.—The relation of the characters of the Pelycosaurian suborder of the Theromorpha to those of the Mammalia may now be seen to be very important. I give a synopsis of the character of these divisions parallel with those of the Batrachia contemporary with them, in order to give a clear idea of the reasons for believing that *the Mammalia are the descendants of the Pelycosauria.*

The table on page 479 shows that the Mammalia agree with the Batrachia in two and part of another character; with the Pelycosauria in six characters, and with other Reptilia in two characters. The Pelycosauria agree with the Batrachia in two and in parts of two other characters, and with other Reptilia in three characters, two of which (Nos. 2 and 3) are of prime importance. Of the characters in which the Pelycosauria agree with the Mammalia, two are of first class importance (Nos. 1 and 5); three are of great but unascertained degree of importance (Nos. 4, 6 and 8), and one (No. 9) is of less importance. The two characters (Nos.

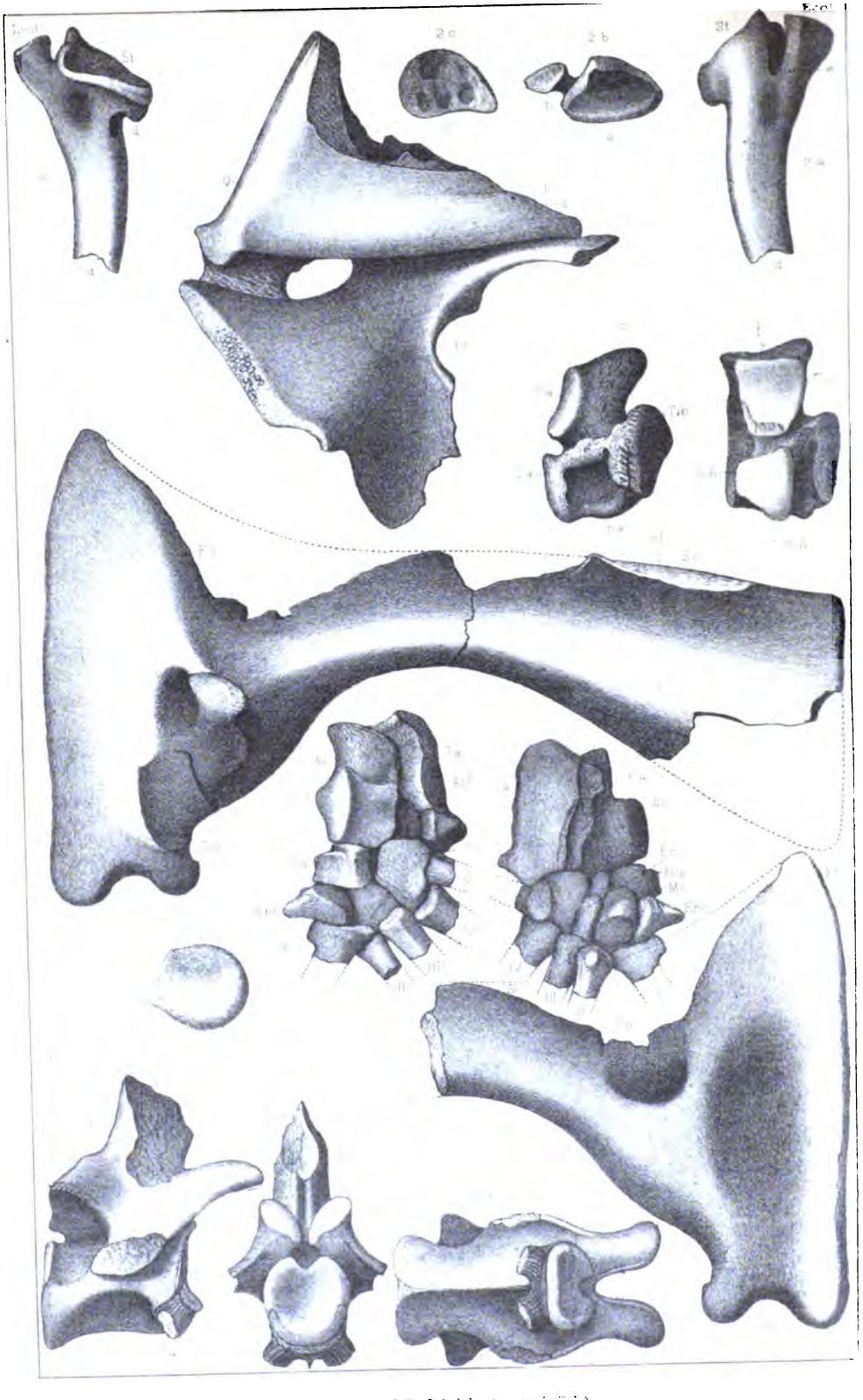
[5] I am just in receipt of an MS. from Dr. Baur, of New Haven, in which he presents an identification of the "internal navicular" bone of some rodents, and which probably existed in the ungulate genera, Pantolambda and Bathmodon. He identifies it with the tibiale, and denies that the astragalus includes that element, but that it consists wholly of the intermedium. This identification will also apply, though Dr. Baur in his manuscript does not make it, to the element which supports the spur in the known Monotremata. It will also explain the nature of the element which occupies the same position in the foot of the Pelycosauria described. The arrangement in this order of reptiles confirms the conclusion reached by Dr. Baur, since the questionable element is here in direct contact with the tibial facet of the astragalus.

| | Batrachia of the Permian. | Pelycosauria. | Other Reptilia. | Mammalia. |
|---|---|---|---|---|
| 1. Basiphenoid axis, | Unossified and with a parasphenoid. | Ossified; no parasphenoid. | Ossified; no parasphenoid. | Ossified; no parasphenoid. |
| 2. Occipital condyle, | Two. | One. | One. | Two. |
| 3. Quadrate bone, | Separate. | Separate. | Separate. | "Coösified with squamosal."— (Albrecht). |
| 4. Postorbitosquamosal arch, | Present. | Wanting. | Present (generally). | Wanting. |
| 5. Coracoid bone, | Small, coössified. | Small, coössified. | Large, distinct. | Small, coössified. |
| 6. Ribs, | Diapophysial. | Intercentral. | Diapophysial and central (in position). | Intercentral. |
| 7. Pelvis, | Without obturator foramen. | Without obturator foramen. | With obturator foramen. | With obturator foramen. |
| 8. Posterior foot, | Intermedium, tibiale, fibulare and centrale distinct. | Intermedium, tibiale, fibulare and centrale distinct. | Tibiale, and centrale not distinct; intermedium and fibulare generally not distinct. | Intermedium, fibulare and centrale distinct; tibiale distinct when present. |
| 9. Humerus, | With condyles. | With condyles and entepicondylar foramen. | No entepicondylar foramen, except Hatteria (Dollo); rarely condyles. | Condyles; frequently entepicondylar foramen. |

2 and 5), in which the Mammalia agree with the Batrachia, are of high importance, but one of them is also a point in which the Pelycosauria agree with both (structure of the coracoid bone, No. 5). There is but one character, the distinctness of the quadrate bone, in which the Batrachia agree with the Reptilia in general.

The preceding comparison renders it extremely probable that the Mammalia are descended from the Pelycosaurian Reptilia. The usual definitions have been invalidated, excepting that of the occipital condyles, but even this is not so absolute a character as has been supposed. In the gecko lizard, Uroplates, the occipital condyle is represented by the exoccipital pieces only, the basi-occipital element being omitted nearly as in the Mammalia. Professor Huxley has regarded it as most probable that the true ancestors of the Mammalia have been the Batrachia. It is evident that the Pelycosauria are in various respects the most Batrachian of the Reptilia, for they agree with them in three and parts of two other characters of the nine above enumerated. One of the latter is the structure of the posterior foot, which displays much less modification from the Batrachian type than that of the ordinary Reptilia.

The first evidence of the resemblance of the Pelycosauria to the Mammalia was empirical and not conclusive. This consisted in the characters derived from the long bones of the limbs. Professor Owen first called attention to this resemblance in the genus Cynodraco, which is a Theromorph reptile. I next pointed out corresponding peculiarities in the humeri of the American Theromorphs. I subsequently recorded some resemblance between the pelvis of the Pelycosaur division, and that of the Monotremata. This was followed by a demonstration of the resemblance between the coracoid of the Pelycosauria and the Mammalia of the Monotrematous order, especially the family of the Platypodidæ. In subsequent papers I added that the structure of the posterior foot approaches near to that of the Monotremata; that the *os quadratum* and the ribs are essentially like the corresponding parts in all the Mammalia; and that the stapes is perforated as in that class. The last three points are essential and fundamental. The three great distinctions between the Mammalia and Reptilia in the skeleton are: (1) in the quadrate bone; (2) in the coracoid bone, and (3) in the occipital condyle. Of these the last only now remains, and this is weakened by the presence of the



Mammalian type in the geckotian lizard already referred to. The only interruption in the series which has not yet been overcome is in the *Columella auris*. No reptile is yet known where that element is divided into incus, orbicularis, and stapes, as in the Mammalia, and some Batrachia (according to Dollo). The probable presence of an osseous incus is, however, an important step in this direction, in mammalian characters. Of course the above comparison with the Monotremata considers the latter order in its proper ordinal definitions, and not in its special subordinate modifications now existing, the Platypodidæ and Tachyglossidæ. Monotremata with dentition like that of the known Jurassic and Triassic Mammalia will doubtless yet be discovered in beds of those ages.

The interesting announcement just made at the meeting of the British Association for the Advancement of Science at Montreal this year may now be referred to. Mr. Caldwell, the holder of the Balfour scholarship, telegraphs that he has discovered that the *Platypus anatinus* is oviparous, and that the segmentation of the egg is meroblastic, as Haeckel gives it in the Studien zur Gastræa Theorie, Jena, 1877, p. 65. This confirms the hypothesis of descent from reptilian ancestors rather than Batrachian.

*Bibliography.* The first mention of the conclusions stated in the preceding pages will be found in the American Naturalist for November, 1884 (published October 20), and December, 1884. In the latter number is a plate illustrative of the same. In the Proceedings of the American Philosophical Society for August, 1884, the same results are set forth at length with a plate accompanying. This paper was not published until November of the same year.

EXPLANATION OF PLATE.

Fig. 1. *Clepsydrops leptocephalus* Cope, right quadrate bone (Q) with condyle and zygomatic process (*z*) from the right. or external side. *Pt*, pterygoid bone of same side displaced so as to be in plane of quadrate, and to be seen from inferior side. One-half natural size.

Fig. 2. Columella auris of the individual of *Clepsydrops leptocephalus* represented in fig. 1; internal side. Fig. 2*a* external side; 2*b* proximal extremity; 2*c* distal extremity; *s*, head of stapes; Ecol. epicolumella; *d*, distal articular surface, especially represented in fig. 2*c*. *e*, stapedial foramen. All figures are half natural size, excepting 2*c*, which is natural size.

Fig. 3. Left half scapular arch of a Pelycosaurian, less clavicle and episternum, one-half natural size; *sc*, scapula; *cl*, facet for clavicle; *cor*, coracoid; *ec*, epicoracoid; *s*, open suture between coracoid and epicoracoid, indicating the immaturity of the animal.

Fig. 4. Dorsal vertebra of a species of Embolophorus, one-half natural size; right side; *a*, from front; *b*, from below; *ic*, intercentrum; *ca*, capitular rib articulation.

Fig. 5. Astragalus of individual figured in fig. 4, one-half natural size; from below. *ca*, *ca*, facets for calcaneum; *na*, do. for navicular; *tib.* 2, do. for bone of spur, or os tibiale. *5a*, same bone from external or calcaneal border; *f*, fibular facet. *5b*, same bone, proximal or fibular extremity.

Fig. 6. Left posterior foot of *Clepsydrops natalis* Cope, superior side, and 6*a*, inferior (plantar) side, two-thirds natural size. *as*, astragalus; *ca*, calcaneum; *na*, navicular bone; *cu*, cuboid; *cuc*, *mc* and *ecc*, entocuneïform, mesocuneïform and ectocuneïform bones, respectively. I, II, III, IV, V, metatarsals. *Tib.* 1, Probable tibial facet. In this specimen the calcaneum is displaced; being turned backwards, so as to present its two astragalar facets (*as'*) anteriorly.

N. B. The use of this plate was kindly granted by the American Philosophical Society.

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## On the structure of the feet in the extinct Artiodactyla of North America. By Prof. E. D. Cope, Philadelphia, Pa.

The structure of the feet of a number of the Artiodactyles of the tertiary beds of North America has already been described. In this paper I enumerate these, and add descriptions of some types which have been hitherto unknown. I commence with the Bunodonta.

### Bunodonta.

*Pantolestes* Cope. The structure of the tarsus only of this Eocene genus is known.[1] The cuboid and navicular bones are distinct from each other and from the cuneiforms, and the ecto- and mesocuneiform are coössified. There are four metatarsals. The laterals (ii and v) are slender; and the medians are distinct but appressed, their adjacent sides being flattened. This foot structure is remarkably advanced considering the early age, Wasatch Eocene, of the period of its existence, and the primitive tritubercular bunodont character of the superior dentition. The selenodont types which appear first in our series of formations, the Oreodontidæ of the White River low Miocene, present a much more primitive type of foot. The camel series is remarkable for the early and continued absence of the first and fifth metapoidal bones. The first known of the line, Poëbrotherium, from the White River beds, has only minute rudiments of them. It is probable the Pantolestes or some member of the Pantolestidæ is an ancestor of Poëbrotherium with a number of lost types intervening.

[1] Cope, Proceedings American Philosophical Society, 1881, p. 188. Paleontological Bulletin, No. 34.

*Elotherium* Aym. The first information respecting the structure of the feet of this genus was furnished by Marsh.[2] He says, "The radius and ulna were separate or very loosely united. The third and fourth metacarpals were nearly equal in size, and the second and fifth larger than the corresponding bones of the pes. In the latter the first digit was wanting, and the fifth rudimentary." This description leaves us in the dark as to the development of the second digit in the posterior foot, and of the second and fifth in the anterior foot. This ambiguous language led me to infer that there are four digits of the anterior foot of the animal described by Marsh, and hence to separate it generically from Elotherium. The first definite information is derived from Kowalevsky from his great memoir on the genus Anthracotherium.[3] He here states distinctly the genus is bidigitate, but with small rudiments of the second and fifth metapoidal bones. He shows also that the lunar is equally supported by the magnum and unciform. In a memoir especially devoted to this genus[4] he also shows that the cuboid, navicular and cuneiforms are distinct, while the ecto- and mesocuneiforms are coössified; the entocuneiforms being absent. The structure of the tarsus in this genus is then as in Pantolestes, and from this genus, or one of the same family, Elotherium no doubt took its origin, through intermediate genera.[5]

### Selenodonta.

*Oreodon* Leidy. We owe to Leidy the following statement regarding the foot-structure of this genus.[6] "What are supposed to be the bones of the forearm and leg are discrete, as in the hog; and the bones of the feet correspond in number with those of this animal. In 1873 Professor Marsh confirmed these statements as regards the metacarpal bones,"[7] and added that "the navicular and cuboid bones were loosely coössified or separate." In 1884[8] I gave a full account of the structure of the limbs in this genus. I mentioned a peculiar feature of the carpus, viz., that the os lunare is

[2] American Journal Sci. Arts, 1873, p. 487, June.
[3] Palæontographica, 1873. p. 188. August?
[4] Loc. cit. XXII, N. F. II, 7 p. 415.
[5] I have given the structure of the anterior leg in *Elotherium imperator* Bulletin U.S. Geol. Surv. Terrs., Vol. V, p. 60.
[6] Extinct Mammalia, Dakota and Nebraska, 1869, p. 72.
[7] Amer. Jour. Sci. Arts, p. 409; Marsh does not credit Leidy with his previous observations.
[8] Proceeds. Amer. Phil. Soc. Pal. Bulletin, No. 38, pp. 508–10.

supported below by the inward extension of the unciform, so that the magnum is below the scaphoideum. I also showed that the cuneiforms are distinct, and that the entocuneiform is wanting.

*Eucrotaphus* Leidy. I have already stated that this genus is tetradactyl anteriorly and posteriorly.[9] I now add that the structure of the limbs and feet is in other respects like that of Oreodon. This is true of the inner extension of the unciform so that the magnum is below the scaphoideum. The inner side of the latter bone in the *Eucrotaphus pacificus* is so excavated, that there was plainly a free trapezium of small size. In the posterior foot the entocuneiform is wanting, and the mesocuneiform is distinct from the ectocuneiform.

*Merycochœrus* Leidy. The first information of the foot structure of this genus is contained in my paper on the Oreodontidæ above cited.[10] The fore and hind feet are there stated to be tetradactyl. I now add that in the *M. montanus* Cope the os magnum is entirely below the scaphoid, and that there is a distinct trapezium. The posterior foot is constituted as in Eucrotaphus. I also observe that the navicular has a peculiar little facet on its distal face near the front of its external edge. This fits a corresponding facet which forms the proximal surface of a ledge, which extends from front to rear on the inner side of the cuboid. In *Eucrotaphus pacificus* the arrangement is similar, excepting that the ledge of the cuboid is interrupted at the middle by a deep excavation. In *Merychyus arenarum* the cuboid is like that of *Merycochœrus montanus*, in regard to this ledge.

*Merychyus* Leidy. The limbs and feet in this genus are quite as in Merycochœrus. The species which I have examined is the *M. arenarum* Cope.

*Leptomeryx* Leidy. We possess as yet no information regarding the limbs and feet of this genus. It is therefore fortunate that I obtained in the White River bed of northeastern Colorado in 1879, a nearly entire skeleton of the *L. evansi* Leidy. The bones were all found close together, and belong to two individuals, and are without admixture of those of any other species.

From these, and inferentially from other specimens, is derived the curious fact, that there are four distinct metacarpals, all supporting digits, while there are but two metatarsals, which are

[9] Loc. cit., p. 504.
[10] Proceeds. Amer. Philosoph. Society, 1884, p. 504.

coössified into a cannon bone. This diversity between the limbs is unparalleled, although an approach to such a condition is seen in the peccary. In this animal, as is well known, there are four distinct digits in the manus, while in the pes, the metatarsals are coössified proximally, and the fifth metatarsal is reduced to a scale. This difference between the two limbs is a further illustration of Mr. Ryder's statement that the posterior limb is in advance of the anterior in grade of development, for which I have endeavored to account by reference to the fact that it is the posterior foot which receives the greater number of impacts in progression. This is because the hind limb is the principal propeller of the body.

In accordance with the structure of the feet, the fore limb is much behind the posterior limb in the fixity of its parts. The ulna and radius are distinct; the head of the latter is a regular transverse oval.

The lunar is mainly supported by the unciform, so much so that the front face of the magnum is not bevelled to fit the former. Behind the face, the edge of the magnum is a little bevelled for the lunar; but the former bone lies almost entirely under the scaphoid. The trapezoides is coössified with the magnum. No distinct trapezium.

The distal extremity of the fibula is not coössified with the tibia, but forms a separate bone, as in the Ruminantia.

The cuboid and navicular are solidly united. The ecto- and mesocuneiforms are distinct, and there is no entocuneiform. The second metatarsal is represented by a flat oval bone, which is borne on the underside of the projecting heel of the third metatarsal. The fifth is of smaller size, and is a scale embedded in a depression of the posterior part of the side of the fourth. Ungues unilateral, trihedral and acute.

*Hypertragulus* Cope. Remains of this genus are as abundant in the White River beds as are those of Leptomeryx, and like that genus I know but one species, the *H. calcaratus* Cope. Unfortunately I have not been able to obtain bones of the skeleton connected with dentition from this formation, although numerous bones occur separately which probably belong to it. The genus is however abundantly represented in the John Day Miocene beds of Oregon, where Leptomeryx does not probably occur. At least no specimens of the latter are to be found in a collection of between one and two hundred individuals of this general type in my

collection. I cannot distinguish the John Day species from the *H. calcaratus*, although the size is generally distinctly larger.[11] In other cases the size is the same. To the John Day specimens then, I refer for the characters of the foot of this genus.

The ulna and radius are coössified. The scaphoid and lunar facets of the radius are well distinguished by an oblique ridge. The carpus is unknown. The median metacarpals are separate; whether the second and fifth are well developed I do not know, but suspect them to be so as in Leptomeryx, since the third and fourth bear no adherent rudiments. The cuboid and navicular bones are united, while the cuneiforms are distinct from them and from each other as in Leptomeryx. There are but two developed metatarsals, and these are distinct from each other. Thus the fore-limb in its ulno- radius exhibits a little advance over Leptomeryx; while in the separate metatarsals it is behind the latter.

*Hypisodus* Cope. This genus is remarkable for its prismatic dentition, being the only Artiodactyle presenting the character in the White River fauna.[12]

It was probably well advanced in foot characters, but of these I know but little. Parts of two tarsi found with the jaws of the *H. minimus* Cope, are referred to the species on account of their very small size and general correspondence. The cuboid and navicular are coössified. Their distal face, especially the navicular part, is so narrow transversely, that it is almost certain that the third and fourth metatarsals are coössified, and that the second and fifth are rudimentary or wanting. There is no trace of facets for the latter on the naviculo-cuboid.

*Poëbrotherium* Leidy. I have fully described the limbs of this genus in the Annual Report of the U. S. Geological Survey of the Territories for 1873,[13] as seen in the *P. vilsoni* Leidy, from the White River beds, and have confirmed them from a fine specimen of the *P. sternbergii* Cope, from the John Day or middle Miocene of Oregon.[14] The characters are: ulna and radius coössified; trapezium and trapezoides present and distinct; magnum supporting part of lunar. Two distinct metacarpals, scales representing

[11] It is probably this species that is cited by Leidy as the *Leptomeryx evansi* in the Report, U. S. Geol. Surv. Terrs. I, p. 216.

[12] See Cope, Annual Report U. S. Geol. Survey Terrs., 1873, p. 501, where the cuboid and navicular are stated to be united.

[13] Annual Report U. S. Geol. Surv. Terrs., 1874, p. 499.

[14] Bulletin U. S. Geol. Surv. Terrs. V, p. 59.

the second and fifth. Navicular and cuboid bones distinct; as are the ecto- and mesocuneiform; entocuneiform wanting. Metatarsals two, distinct; second and fifth represented by scales.

### Observations on the Phylogeny.

I have maintained[15] that the selenodont dentition is a derivative of the bunodont, a proposition which seems unavoidable from a mechanical point of view. The testimony of palæontology is also in its favor, since in America the oldest artiodactyle, Pantolestes, is bunodont. Kowalevsky in the phylogenetic table given in his monograph of Anthracotherium[16] does not commit himself as to this point, but allows the development of the two types of dentition to appear to have been contemporary and from some common origin. He then derives from such a common point of departure first, the Hyopotamidæ, which first appear in the Eocene, and second, the ancestors of the Anoplotheriidæ. From the Hyopotamidæ he derives all the modern Selenodonta, exclusive of the Camelidæ. The latter group he omits from his table, doubtless because his information on the subject was insufficient. The main line of origin of the Selenodonta is divided early in Miocene time, the genus Gelocus giving origin to the Pecora, and the genus Hyæmoschus to the Tragulina.

In describing the characters of the genus Poëbrotherium for the first time, I remarked as follows:[17] "The present genus is a more generalized type than Gelocus, and in its distinct trapezoid and distinct metacarpals represents an early stage in the developmental history of that genus. It also presents affinity to an earlier type than the Tragulidæ which sometimes have the divided metacarpals but the trapezoides and magnum coössified. In fact Poëbrotherium, as direct ancestor of the camels, indicates that the existing Ruminantia were derived from three lines represented by the genera Gelocus for the typical forms, Poëbrotherium for the camels, and Hyæmoscus for the Tragulidæ."

These views being then established on sufficient evidence, it remains to make such additions as the facts cited in the present paper indicate. First in importance comes the place in the phylogeny of the Selenodonta, of the Oreodontidæ. The peculiar inward extension of the unciform bone, already ascribed to them, charac-

[15] Journal Academy Natural Sciences, 1874.
[16] 1873 (? 4) p. 152.
[17] Bulletin U. S. Geol. Survey Terrs. Vol. I, No. 1. p. 26, Jan. 1874.

terizes also among extinct forms the genus Leptomeryx, and probably Hypertragulus. Among recent ruminants it is only seen in the Tragulidæ.[18] If we arrange these types in serial order we find the modifications of form to be generally identical with those of the other ruminant lines, in the coössification of the bones of the legs and feet. This series may then be regarded as phylogenetic. The peculiar structure of the carpus of the Oreodontidæ, puts them out of the question as ancestors of any type of existing ruminants other than the Tragulina. Whether they themselves can be traced to a five-lobed, or to a four-lobed bunodont ancestor, remains an undecided question. It is not, however, probable that a five-lobed form has been intercalated in a series, both of whose extremities are four-lobed. If this be true, the Oreodontidæ must be regarded as an ancestral type of Selenodonta, coëqual with the Hyopotamidæ, and it may well be questioned whether the latter can have been ancestors of the existing Ruminantia, whose molars are four-lobed. So the present investigation does not disclose the ancestral stock of the Pecora. In North America we have not progressed further in the solution of this question than I reached in 1877,[19] after a study of the genera Cosoryx Leidy, and Blastomeryx Cope. I had already[20] suggested that the former genus is the ancestor of the Cervidæ, but subsequently[21] remarked: "It is not probable that this genus is the immediate ancestor of Cervus, from the fact that the molar teeth display in their prismatic form a higher degree of specialization than belongs to that genus. It is probable that the true ancestral form combined the dental type of Cervus with its distinct roots and short crowns of the molars, with the type of horns here described." I at that time included a species (*Cosoryx gemmifer* Cope) in the genus provisionally, which has the type of molars in question. Having discovered another larger species which has the same type of molars, I at once distinguished the provisional group in which I had placed the *C. gemmifer*, Blastomeryx, as a genus; and in describing the species (*B. borealis*) observed as follows:

"In brief, its molars differ from those of Cosoryx ("Dicrocerus") much as those of the deer differ from the molars of the antelope.

[18] Among Perissodactyles it occurs in Tapirus and the Rhinocerontidæ.

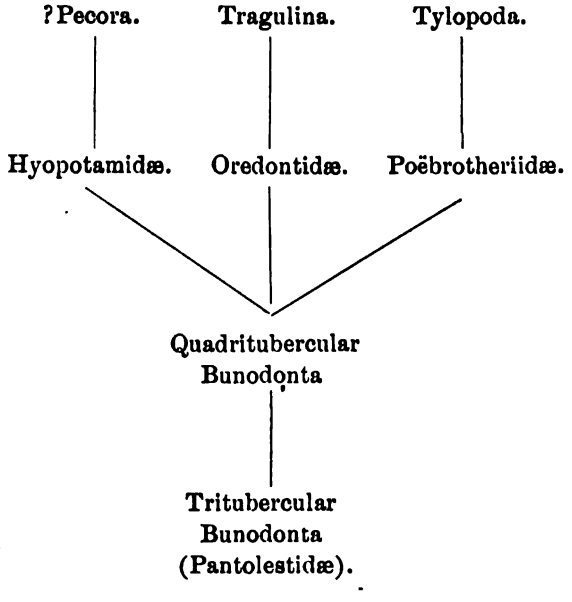
[19] Proceedings Amer. Philos. Soc., p. 223.

[20] Proceedings Academy Philadelphia, 1871, p. 149.

[21] Report Expl. Surv. W. of 100th Mer. U. S., G. M. Wheeler in charge, iv, pt. ii, p. 349, 1877.

While Cosoryx ("Dicrocerus") was probably the ancestor of Antilocapra, Blastomeryx was the ancestor of Cervus or Cariacus." This opinion expresses all the information I possess on the subject at present. It remains to ascertain the structure of the anterior feet in Hypisodus, which is the earliest genus of Ruminantia known to have prismatic molars.

The following table will represent the views expressed in the preceding pages:

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ON CTENACANTHUS AND GYRACANTHUS FROM THE CHEMUNG OF PENNSYLVANIA. By PROF. E. W. CLAYPOLE, Buchtel College, Akron, O.

[ABSTRACT.]

OF the twenty-two species of *Ctenacanthus* described from America, only one, *Ct. vetustus*, New., is from the Devonian rocks. This one was found in the Huron shale of Ohio, considered the equivalent of the Portage of New York. The occurrence therefore of a small specimen of this genus in the Chemung of Pennsylvania deserves

notice. The slab containing it was sent to me with other fossils by an intelligent and accurate collector Mr. A. T. Lilley of Bradford Co. It is a cast of one-half of the spine and is quite perfect. It measures only $2\frac{3}{4}$ inches in length, less than half that of *Ct. vetustus*, and for it I propose the name of *Ct. Chemungensis*.

More worthy of note is another specimen sent me at the same time by the same collector. This is a specimen which I am quite unable to distinguish from *Gyracanthus Alleni* Newb. of the Cuyahoga shale in Medina Co., Ohio. *Gyracanthus* has hitherto been found only in the Carboniferous Rocks and has been considered so characteristic of that system that in the Palaeontology of Ohio, Dr. Newberry wrote:

"*Gyracanthus* is found exclusively in the Coal Measures abroad, and these specimens in the Cuyahoga shale give a decided Carboniferous character to the rock in which they occur."

The occurrence therefore of *Gyracanthus* and especially of a Lower Carboniferous species in the Cuyahoga shale is a fact which helps to link together the Upper Devonian and the overlying system.

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STRUCTURE OF THE SIPHON IN THE ENDOCERATIDÆ. By Prof. ALPHEUS HYATT, Curator Society Natural History, Boston, Mass.

[ABSTRACT.]

THE siphon of this group has several distinct forms. In the Endoceras it is composed of funnels. The interior is filled by sheaths secreting solid conical caps with an amorphous structure, and in the centre is a tube, apparently open and formed originally by the conchiolinous terminations of the sheaths. This is the endosiphon as I have called it. A second form of siphon is found in Actinoceras with the well known structure described by Barrande, and I have now to add a third type in a new genus, which I propose to call Choanitoceras. In this genus the composition of the siphon is not ascertained, the remains being exclusively those of the hard, unyielding endosiphon and sheaths. The sheaths were evidently present as in Endoceras and Actinoceras,

and their conchiolinous character is shown by the remains of the tubular points which extend posteriorly and are much elongated and deeply invaginated into each other. They are imperforate and thus dissimilar to those of Endoceras, being also fewer in number. The principal distinctions, however, lie in the fact that the endosiphon is sometimes surrounded by a thick wall, which is also absent in some parts of the form as in some specimens, and in the columnar structure of the deposits between the sheaths. These last fill the interior of the siphon and abut against a continuous wall which covers the exterior. These deposits resemble those of a Belemnite so closely that I feel that until the siphon is known there is still a doubt of the true affinities.

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LARVAL THEORY OF THE ORIGIN OF TISSUE. By Prof. ALPHEUS HYATT, Curator Society Natural History, Boston, Mass.

[ABSTRACT.]

RECENT investigations by Balbiani, Bütschli and Engelmann have removed almost every obstacle, which formerly existed, to the close homology of the single cell among Metazoa with a full-grown adult Protozoön. We can now even closely compare the nuclei of the Protozoa and its changes during conjugation and subsequent casting off of part of the nucleus, to the casting off of polar cells in the egg. The heads of the spermatozoön in the Calcispongiae have been shown, by Polèjaeff, to arise from division of a part of the nucleus, the other or central part either remaining quiescent, or, as this author states, forming the tails. Almost every author, especially La Valette St. George, the most thorough student of this subject, consider all spermatozoa as derived from simple processes of cell division. The essential and general character of reproduction among Protozoa is similar, being, as is well known to observers, fissiparous division of the whole body, but this division takes place in the adults at the end of a series of transformations, and is not characteristic of larval stages. The building up of the tissue in Metazoa is due to the quick and rapid division of cells, and if it is granted that Metazoa may be aggregates of Protozoa, they must be considered, in fact, larval

forms descended from Protozoa and inheriting the tendency to reproduction, by fissiparous division, at an early stage. In other words, they reproduce while still larvæ and before passing through any transformations, except the very primitive ones which precede and include the nucleated stage.

This picture is completed by the zonoblastic theory of Minot which enables us to see that the sexes originated from the primary differentiation of the nucleus of the egg into two sexual elements, and to account for their differentiation in the same way that we can account for the sexes in adult Protozoa, namely, by the action of natural and sexual selection upon a bisexual form.

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STRUCTURE AND AFFINITIES OF BEATRICEA. By Prof. ALPHEUS HYATT, Curator Society Natural History, Boston, Mass.

[ABSTRACT.]

THIS remarkable fossil is neither a sponge, an ally of Stromatopora, a coral allied to Cystiophyllum, a cephalopod allied to Endoceras, nor a mollusk allied to the Hippuritidae, as supposed by various authors.

It has a cellular structure similar to the Foraminifera, and possesses stolons, uniting these cells with each other.

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THE OSTEOLOGY OF OREODON. By Prof. W. B. SCOTT, College of New Jersey, Princeton, New Jersey.

[ABSTRACT.]

ALTHOUGH this genus was discovered and named more than thirty years ago, very little has been known of its osteology, and consequently its systematic position has been a matter of great doubt. The genus belongs unmistakably to the Artiodactyla and although there are many striking resemblances to the Suidæ, there can be no doubt that it was one of the Ruminants. The skull and dentition have long been known from the accurate descriptions of Dr.

Leidy and so need little remark here. The cervical vertebræ are plainly of the ruminant pattern, markedly so in the case of the axis; the thoracic vertebræ have very long and prominent spines, and small bodies, slightly amphicœlous; the lumbars are very heavy, probably five in number, with short spines and broad, flat, transverse processes; the sacrum has but two vertebræ which touch the ilium with two or three ankylosed to these. The tail was long or slender.

The limbs were remarkably long compared with the size of the trunk, and with the short head and short metapodials give the skeleton a very wolf-like aspect. The ulna and radius are distinct throughout their entire length; the carpus consists of eight bones (including the pisiform) which are very suilline in character, as are the short and unankylosed metacarpals. The ungual phalanges are long and pointed, much like those of Hyopotamus. The most remarkable fact in the osteology of Oreodon is the *presence of a rudimentary pollex*, the only Artiodactyl in which it has ever been found.

The pes is very suilline in character and resembles that of Hyopotamus, containing four free metatarsals of nearly equal size.

As regards the systematic position of the *Oreondontidæ*, they must be regarded as a peculiar side branch of the earliest Selenodonta which retain many features of their Bunodont ancestry. The most interesting fact which they show is that the Artiodactyla, like the Perissodactyla, were derived from a primitive group of pentadactyl ungulates.

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HISTORICAL VIEW OF THE FOSSIL FLORA OF THE GLOBE. By Prof. LESTER F. WARD, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

THE writers of antiquity make no mention of any form of vegetable petrifaction. The earliest allusion to the subject was made by Albertus Magnus in the thirteenth century. Agricola and Gesner treated of petrified wood in the sixteenth century. The first mention of any kind of vegetable impression in the rocks was

made by Daniel Major of Jena, in 1664. In 1699 Edward Lhwyd of London wrote an extensive treatise on such impressions. He maintained that they were the remains of plants that had perished in the Noachian deluge. In 1709 Scheuchzer of Switzerland defended this view in his "Herbarium diluvianum," a large work in which he described and figured many fossil plants, referring them to species living in Europe. In 1718 this author went so far as to classify the fossil plants according to the system of Tournefort. In 1723 he published a new edition of the "Herbarium diluvianum," in which he introduced this classification and enumerated 445 species. A powerful reaction against this method followed; comparisons with living plants were carefully made which failed to establish the identity of the fossils. The idea of their exotic origin was thereupon suggested and for a time prevailed, but towards the close of the eighteenth century this in turn gave way to the true view of the existence of former geologic periods with floras of their own differing from that of the present. Baron von Schlotheim headed this new school and was followed by Count Sternberg and Adolphe Brongniart, who jointly founded the science of vegetable paleontology in the first quarter of the present century.

The first attempt to place it on the footing of a systematic science was made by the Rev. Henry Steinhauer of Bethlehem, Pennsylvania, in a paper read before the American Philosophical Society and published in its "Proceedings" for the year 1818. In this paper he described and figured ten species of Waller's genus Phytolithus, which was made to embrace nearly all forms of vegetable fossils. Two years later Schlotheim in his "Petrefactenkunde" applied specific names to seventy-eight fossil plants. Brongniart, in his "Prodrome" published in 1828, went much farther. He referred many fossil plants to living genera and created a large number of new extinct genera. He enumerated 501 species, many of which were fully characterized and thoroughly illustrated in his "Histoire des végétaux fossiles."

A census of fossil plants was taken by Unger in 1845 which showed that the number of known species had increased to 1,648. In 1848 Göppert made a similar enumeration and found 2,055 species. The extraordinary activity that followed in the developing of new fossil floras rendered it possible for Schimper in 1874 to describe about 6,000 species in his great work "Traité de palé-

ontologie végétale." The decade which has elapsed since the appearance of that work has witnessed extensive investigations in this field, particularly in the arctic regions and in the United States, and the number of fossil species now known to science is probably between eight and nine thousand.

[A table accompanied the paper showing the numerical development of the fossil flora.]

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GEOLOGICAL VIEW OF THE FOSSIL FLORA OF THE GLOBE. By Prof. LESTER F. WARD, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

THE most ancient vegetable remains known are two species of Oldhamia from the Cambrian of Ireland. From the Lower Silurian forty-four species, chiefly marine algae, have been named. Among these, however, are included the earliest terrestrial forms, viz., *Eopteris Morierei*, Sap., *Sphenophyllum primaevum*, Lx., and two other vascular plants from the Cincinnati group. Of the thirteen species of the Upper Silurian five are vascular plants, and these include *Cordaites Robbii*, Dawson, from Hérault. The Devonian furnish 188 species of fossil plants in which ferns play the leading rôle, while from Permo-carboniferous strata nearly 2,000 species are known. Only sixty-seven species are found in the whole of the Trias. With the Rhetic a new impulse is felt increasing to the Oolite, in which 419 species occur. The Upper Jurassic and lower Cretaceous are sparingly supplied with the remains of vegetation, but in the Cenomanian, to which the beds of Atane, Greenland and our own Dakota group of Kansas and Nebraska are referred, nearly 500 species of fossil plants have already been found. The Turonian, with its probable equivalent in the west, the Fort Benton group, is nearly destitute of vegetable remains, but the Senonian immediately overlying it with which the Canadian geologists have correlated certain rich plant beds of British Columbia, and to which Heer's flora of Patoot, Greenland, must be referred, yields more than 350 species. The Laramie group of the western United States is thought to be extreme upper Cretaceous. This is very rich in plants and 333 species have already been described from the horizon.

The Tertiary flora is much more abundant even than that of the Carboniferous. The Eocene furnishes nearly 800 species (including our Green River group and the Paleocene beds of Sézaane and Gelinden). The Oligocene of Europe yields a somewhat larger number. The maximum is attained in the Miocene, from which more than three thousand fossil plants are known. The Miocene practically closes the geological series so far as vegetable paleontology is concerned. Only about 150 Pliocene species exist, and a still smaller number from the Quaternary.

[The paper was illustrated by a table showing the flora of each geological formation, and by a diagram illustrating the thickness of the strata in each and the fluctuations in the development of plant life.]

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BOTANICAL VIEW OF THE FOSSIL FLORA OF THE GLOBE. By Prof. LESTER F. WARD, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

I. *First appearance of types.* THE Oldhamias of the Cambrian, mentioned in the last paper, are marine algae of the order Florideae. The Ferns, Equisetineae, and Lycopodineae all appeared in the Lower Silurian. One species of Cordaites, which is now regarded as the ancestral type of the Coniferae, occurs in the Upper Silurian. The Rhizocarpeae, according to Dawson, existed in the Devonian of Canada and Brazil. The Cycadaceae and the Monocotyledons have their earliest known representatives in the Carboniferous. The order Gnetaceæ is represented, according to Heer, in the Oölite of Siberia by his species *Ephedrites antiquus*. The Dycotyledons first appeared in the Urgonian of Kome, Greenland, through Heer's single species, *Populus primæva*. All three of the divisions of dicotyledonous plants occur in great abundance in the Cenomanian. If the genus Selaginella is regarded as belonging to the Ligulatæ, this small transitional type also first appears in the Cenomanian, at Atane, Greenland.

All the leading types of vegetation are thus introduced without coming down the geological scale later than the middle Cretaceous.

II. *Age of maximum relative predominance of each type.* The marine algæ, being the only vegetation, were supreme during the Cambrian and early Silurian. The maximum relative predominance of each of the other principal types was reached as follows: The Ferns in the Permian, the Equisetineæ and Lycopodineæ in the Carboniferous, the Cycadaceæ in the Lias or Oölite, the Coniferæ in the Wealden or Neocomian, the Monocotyledons in the Eocene, the monochlamydous Dicotyledons in the Cenomanian, the polypetalous Dicotyledons in the Miocene, and the gamopetalous Dicotyledons in the present living flora of the globe.

III. *Probable true period of origin and of maximum absolute development of each type.* Cellular Cryptogams of some kind probably lived in the Laurentian and account for the graphite beds and dark, carbonaceous matter of certain Archæan rocks. Being an heterogeneous group their later representatives belonged to entirely different families. If we include the Fungi the number of species is probably greater in the living flora than it was at any geological epoch. The Ferns, Equisetineæ, and Lycopodineæ probably all originated in the Lower Silurian and reached their absolute maximum in the Carboniferous. The Cycadaceæ may have originated as early as the Devonian. They must have attained their absolute as well as their relative maximum development in the middle Jurassic. The Coniferæ through their archaic form, the Cordaiteæ, began in the Lower Silurian. They attained their full maturity in the Cretaceous and are now on the decline. The Monocotyledons probably date back to the Lower Carboniferous or Devonian and reached their highest expression in the palms whose reign occupied the early Tertiary. These also are probably now waning. The Dicotyledons must have had their real origin in the lower Jura or upper Trias. Their absolute probably coincides with their relative development, the Apetalæ being now declining, the Polypetalæ about stationary, and the Gamapetalæ rapidly advancing.

[Diagrams showing the observed relative development and the probable origin and progress of each of the principal types of vegetation were employed to illustrate this paper.]

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THE TORSION OF LEAVES. By Prof. W. J. BEAL, Agricultural College, Mich.

[ABSTRACT.]

WHEN slightly wilted, *Chenopodium album* turns one edge of most leaves toward the sky, probably because the petiole is slightly compressed.

The leaves of both species of our *Typha* twist with the sun; the same is true of *Sparganium*. Most leaves of *Acorus Calamus* twist a little with the sun, especially toward the tip, though some twist in the opposite direction.

The leaves of *Fritillaria imperialis* twist with the sun. Those of *Allium porrum*, *Allium carinatum* twist well, and all against the sun. The leaves of *Allium cernuum* twist indifferently as to direction, and the twist is near the base where shaded. The leaves of several species of *Iris* twist against the sun, though on some leaves take both directions.

The ends of the leaves of *Gladiolus* all, or nearly all, twist against the sun. All of the above leaves are erect or nearly so. The leaves and bracts of *Liatris scariosa* are more or less horizontal and most twist with the sun, or what would be so, were the leaves tipped up erect. The true upper side of this leaf has the midrib most prominent and contains eighteen stomata to about twelve for the lower side. The ends of the leaf turn to the right as the main axis is held before us. The leaves of *Cyperaceæ*, so far as seen are without torsion.

The leaves of *Phleum pratense*, *Bromus secalinus*, Barley, Clawson wheat, *Triticum repens*, twist with the sun. The leaves of *Panicum capillare*, *Zizania aquatica* twist about as much one way as the other. The leaves of seedling oats, so far as seen, nearly all twist against the sun; those of *Setaria glauca* twist uniformly and well against the sun, while leaves of *Setaria verticillata*, *S. viridis*, *S. Italica* rarely twist any. The leaves of many other grasses were studied. The anatomy of leaves, the overlapping edge of the leaf sheath, the action of wind, sunshine and shade, were taken into account. In many cases, especially when young, the leaf twists most toward the tips; in some older leaves it is confined to the base. In some cases, most likely the sun has nothing to do with the torsion, but the excess of growth in the margins of the blade or petiole, especially when the midrib is not very stout.

Torsion aids slender leaves in maintaining an erect position. It helps expose different portions of the leaf to direct sunlight, at different times of the day. There is nothing more wonderful in the opposite direction assumed by leaves, than in the opposite course taken by stems of *Calystigia sepium*, all of which are good twiners.

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POLARITY OF LEAVES OF ERIGERON CANADENSE. By Prof. W. J. BEAL, Agricultural College, Mich.

[ABSTRACT.]

ON smaller stems of moderate growth, in a rather still place, well exposed to the sun, the slender leaves below the flowers show polarity; those on the north and south sides of the stem showing torsion, while those on the east and west side show little, if any.

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STOMATES ON SEEDS. By Prof. GEO. MACLOSKIE, College of New Jersey, Princeton, N. J.

[ABSTRACT.]

IT is usually said that seeds have no stomates, except of Canna.

I have shown that the seed of Magnolia have stomates, and those of *Lilium speciosum* have a few.

I now add to the list of seeds bearing stomates the following genera, Polygala, Hickory, Black walnut, Viola, Caulophyllum, Beech. Arisæma has a covering with stomates on its seeds, which is probably accessory to, and not really a coat of the seed.

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THE INFLUENCE OF CROSS FERTILIZATION UPON THE DEVELOPMENT OF THE STRAWBERRY. By Prof. WILLIAM R. LAZENBY, Ohio State University, Columbus, Ohio.

[ABSTRACT.]

FEW questions at the present time are exciting more interest among small fruit culturists than the one of cross fertilization. Whether the fecundation of one variety of plant by another of the

same or different species, affects the size, quality, and general appearance of the fruit so fertilized is a subject that has called forth no little discussion during the past year. Although much has been written upon this topic and various conjectures have been offered the writer is not aware that it has been made the subject of any well planned and carefully executed experiments.

In order to throw some light upon this important, yet wholly unsettled question, some investigations were conducted at the Ohio Experiment Station the past summer, a brief report of which is herewith given.

Some time before the period of blossoming of the strawberry it was decided to make a careful study of the different varieties with special reference to the following points:—

(1) To what extent are the so-called pistillate varieties stamen-bearing? (2) What is the comparative difference of pollen production in the bisexual or perfect forms? (3) What is the influence upon the fruit by fertilizing a well-marked pistillate variety by pollen from different and well characterized bisexual or perfect varieties? As the station had upwards of sixty varieties of the strawberry in a fruiting condition, all selected with care, true to name, and grown in plats sufficiently large to admit of reliable comparisons and estimates as to productiveness, quality, etc., the opportunities for conducting the investigations named above were exceedingly good.

In regard to the first two points we will only state that some abortive stamens were found in every one of the thirty-six so-called pistillate varieties that were examined. In every instance but one, grains of pollen were also discovered. These pollen grains, however, were often imperfect. In the bisexual or perfect varieties there was quite a marked variation as regards the number of stamens. Another interesting fact is that the quantity of pollen bears no definite relation to the number of stamens.

Some varieties, like the Sharpless, showing a comparatively large number of stamens produced a small amount of pollen, while in other varieties like the James Vick, the amount of pollen per blossom was much greater, although the average number of stamens was considerably less.

In order to answer the third question,— the influence upon the fruit of pollen from different varieties, a subject with which this paper has especially to deal,—the following plan was adopted: some

wooden boxes eighteen inches square and ten inches deep, without bottoms, were prepared. Before the strawberries blossomed a dozen or more of these boxes were placed at different points in a large plat of the Crescent seedling variety. Each box was placed so as to enclose some strong, healthy, vigorous plants. When put in position they were covered with a single plate of glass whitewashed, or with a light frame over which was stretched oiled cotton cloth. The plants thus enclosed were kept securely covered until they reached the period of full bloom. At this time pollen was conveyed to all blossoms that were in a suitable condition, all others being carefully removed, from the following well-marked bisexual varieties, viz.: Cumberland, Triumph, Sharpless, Charles Downing, and James Vick. Pollination was effected by simply removing some blossoms of the above named varieties when they were shedding their pollen, and rubbing them gently but thoroughly over the stigmas of the pistils of the Crescent. After this operation had been performed the plants were kept securely covered until it was seen that fertilization had taken place, or until the period of blossoming was over. In every case two boxes, as far removed as the limits of the plat, about one-eighth of an acre, would admit, were treated in the same way; that is, duplicate tests with each variety were made, and in two cases the plants in three boxes each were pollinized with the same variety.

In three boxes which were removed each from the others in the same manner the plants were kept covered, but no attempt at pollinization was made; the object being to find out whether, under those circumstances, self-fertilization would or would not take place. In these boxes no blossoms whatever were removed and they were left to themselves excepting an occasional examination to see if the plants remained healthy and vigorous. The results of these tests may be briefly stated as follows: In two of the three boxes where there was no attempt at artificial pollinization no fruit whatever was developed, although the plants blossomed naturally and appeared strong and vigorous. In the third box a number of imperfect berries were found upon the plants growing at one side, but no fruit whatever on the remaining plants.

It was noted during the course of the experiment that in one or two instances the covers of the boxes had been interfered with, and partially removed. It is more than probable that such had been the case with this box. In all of the boxes where the plants

were artificially pollinized, fertilization followed and a greater or less number of berries was the result.

Although somewhat imperfect, in every instance there was a marked resemblance in shape, size, color, and general appearance to the fruit of the male parent. All of the duplicate tests showed exactly the same results.

Owing to an early and long protracted drought strawberries grown in Central Ohio the past season were not nearly as large or perfect as they usually are. The same cause affected the cross-bred berries, yet, despite this, the characteristics of the male parent were plainly evident in each case. So strongly did they predominate that there was little or no resemblance to the fruit of the female parent. No one could have named any one of the four cross-bred samples as Crescents, while every one acquainted with the varieties from which the pollen was taken could readily identify the fruit it had fertilized as the same variety. Where the pollen of the Cumberland Triumph was used the color was very light and the berries exceedingly soft. Those fertilized with the pollen of the James Vick were small but very firm and remarkably perfect in outline. The cross with the Charles Downing showed marked resemblance in shape, color, and consistency to this well known variety. It showed also the characteristic gloss of this fruit. Where the Sharpless was used as the male parent the berries were large and irregular, the fruit of this cross being much more imperfect than that of any other cross. Thus far we have only spoken of the effect produced by cross-fertilizing one well known pistillate variety of the strawberry, the Crescent.

A further test was made in the same manner by pollinizing a comparatively new pistillate variety, the Manchester, with the Sharpless and with the James Vick, two of the four varieties used to fertilize the Crescent. The results obtained were precisely similar to those already described. The Manchester fertilized by the Sharpless produced large berries resembling the Sharpless, and possessing few of the characteristics of the Manchester. When artificially pollinized by the James Vick, the Manchester produced a small, firm, perfect, and regular berry like that of the male parent.

In regard to the effect of cross-fertilization upon the flavor we cannot speak as confidently as of the characteristics just now named. Being anxious to save the seed this point was not

thoroughly tested. In our judgment, based upon a careful test of only a few berries, the difference here was just as pronounced as it was in the size, shape, and color of the fruit.

In addition to the tests already reported the following were made.

Four boxes like those already described were placed over plants of the following bisexual or perfect varieties, viz.: Iron Clad, Finch's Prolific, Charles Downing and Sharpless. These were simply covered during the whole period of blossoming. In each case fair samples of fruit were produced, differing in no respect from the fruit of the same variety on plants growing under natural conditions. Four more boxes were placed over the following pistillate varieties, viz.: Windsor Chief, Gypsy, Photo, and Huddleston's Favorite. The result was no fruit whatever, although each of these varieties were fairly productive where the plants were not thus covered. Two questions naturally arise: (1) If the influence of the pollen is as marked as our experiments indicate, why has it not been more generally observed? That the same variety of strawberry did often present great differences has frequently been noticed, but has usually been referred to the influence of the soil, fertilizers, season, climate, etc.

Several years ago I observed that the Crescent grown in a certain garden and fertilized by the Wilson was a very different berry from the Crescent grown in another garden and fertilized by the Charles Downing. This difference was then, however, all attributed to other causes.

(2) If the effect of cross-fertilization is as marked in every instance as in the cases described how do our well known varieties preserve their characteristics? In reply to this question we must remember: (1) That pistillate varieties have not been so long or generally cultivated as bisexual or perfect varieties. (2) That many of the so-called pistillate varieties produce more or less pollen. (3) As a rule quite a number of varieties of the strawberry are grown in close proximity, and the plants are probably fertilized by pollen from all the stamen-bearing varieties. Hence the influence of one may be neutralized by that of another. In all our sixty varieties growing side by side, about two-thirds of which are pistillate, the characteristics of the fruit of each were preserved, and no one could tell by an examination of the fruit alone, by what pollen any one variety had been fertilized. Yet in every case where a variety was known to be fertilized by the pollen from just one other variety the influence was marked and decisive.

made by Daniel Major of Jena, in 1664. In 1699 Edward Lhwyd of London wrote an extensive treatise on such impressions. He maintained that they were the remains of plants that had perished in the Noachian deluge. In 1709 Scheuchzer of Switzerland defended this view in his "Herbarium diluvianum," a large work in which he described and figured many fossil plants, referring them to species living in Europe. In 1718 this author went so far as to classify the fossil plants according to the system of Tournefort. In 1723 he published a new edition of the "Herbarium diluvianum," in which he introduced this classification and enumerated 445 species. A powerful reaction against this method followed; comparisons with living plants were carefully made which failed to establish the identity of the fossils. The idea of their exotic origin was thereupon suggested and for a time prevailed, but towards the close of the eighteenth century this in turn gave way to the true view of the existence of former geologic periods with floras of their own differing from that of the present. Baron von Schlotheim headed this new school and was followed by Count Sternberg and Adolphe Brongniart, who jointly founded the science of vegetable paleontology in the first quarter of the present century.

The first attempt to place it on the footing of a systematic science was made by the Rev. Henry Steinhauer of Bethlehem, Pennsylvania, in a paper read before the American Philosophical Society and published in its "Proceedings" for the year 1818. In this paper he described and figured ten species of Waller's genus Phytolithus, which was made to embrace nearly all forms of vegetable fossils. Two years later Schlotheim in his "Petrefactenkunde" applied specific names to seventy-eight fossil plants. Brongniart, in his "Prodrome" published in 1828, went much farther. He referred many fossil plants to living genera and created a large number of new extinct genera. He enumerated 501 species, many of which were fully characterized and thoroughly illustrated in his "Histoire des végétaux fossiles."

A census of fossil plants was taken by Unger in 1845 which showed that the number of known species had increased to 1,648. In 1848 Göppert made a similar enumeration and found 2,055 species. The extraordinary activity that followed in the developing of new fossil floras rendered it possible for Schimper in 1874 to describe about 6,000 species in his great work "Traité de palé-

ontologie végétale." The decade which has elapsed since the appearance of that work has witnessed extensive investigations in this field, particularly in the arctic regions and in the United States, and the number of fossil species now known to science is probably between eight and nine thousand.

[A table accompanied the paper showing the numerical development of the fossil flora.]

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GEOLOGICAL VIEW OF THE FOSSIL FLORA OF THE GLOBE. By Prof. LESTER F. WARD, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

THE most ancient vegetable remains known are two species of Oldhamia from the Cambrian of Ireland. From the Lower Silurian forty-four species, chiefly marine algae, have been named. Among these, however, are included the earlicst terrestrial forms, viz., *Eopteris Morierei*, Sap., *Sphenophyllum primaevum*, Lx., and two other vascular plants from the Cincinnati group. Of the thirteen species of the Upper Silurian five are vascular plants, and these include *Cordaites Robbii*, Dawson, from Hérault. The Devonian furnish 188 species of fossil plants in which ferns play the leading rôle, while from Permo-carboniferous strata nearly 2,000 species are known. Only sixty-seven species are found in the whole of the Trias. With the Rhetic a new impulse is felt increasing to the Oolite, in which 419 species occur. The Upper Jurassic and lower Cretaceous are sparingly supplied with the remains of vegetation, but in the Cenomanian, to which the beds of Atane, Greenland and our own Dakota group of Kansas and Nebraska are referred, nearly 500 species of fossil plants have already been found. The Turonian, with its probable equivalent in the west, the Fort Benton group, is nearly destitute of vegetable remains, but the Senonian immediately overlying it with which the Canadian geologists have correlated certain rich plant beds of British Columbia, and to which Heer's flora of Patoot, Greenland, must be referred, yields more than 350 species. The Laramie group of the western United States is thought to be extreme upper Cretaceous. This is very rich in plants and 333 species have already been described from the horizon.

The Tertiary flora is much more abundant even than that of the Carboniferous. The Eocene furnishes nearly 800 species (including our Green River group and the Paleocene beds of Sézaane and Gelinden). The Oligocene of Europe yields a somewhat larger number. The maximum is attained in the Miocene, from which more than three thousand fossil plants are known. The Miocene practically closes the geological series so far as vegetable paleontology is concerned. Only about 150 Pliocene species exist, and a still smaller number from the Quaternary.

[The paper was illustrated by a table showing the flora of each geological formation, and by a diagram illustrating the thickness of the strata in each and the fluctuations in the development of plant life.]

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BOTANICAL VIEW OF THE FOSSIL FLORA OF THE GLOBE. By Prof. LESTER F. WARD, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

I. *First appearance of types.* THE Oldhamias of the Cambrian, mentioned in the last paper, are marine algae of the order Florideae. The Ferns, Equisetineae, and Lycopodineae all appeared in the Lower Silurian. One species of Cordaites, which is now regarded as the ancestral type of the Coniferae, occurs in the Upper Silurian. The Rhizocarpeae, according to Dawson, existed in the Devonian of Canada and Brazil. The Cycadaceae and the Monocotyledons have their earliest known representatives in the Carboniferous. The order Gnetaceæ is represented, according to Heer, in the Oölite of Siberia by his species *Ephedrites antiquus*. The Dycotyledons first appeared in the Urgonian of Kome, Greenland, through Heer's single species, *Populus primæva*. All three of the divisions of dicotyledonous plants occur in great abundance in the Cenomanian. If the genus Selaginella is regarded as belonging to the Ligulatæ, this small transitional type also first appears in the Cenomanian, at Atane, Greenland.

All the leading types of vegetation are thus introduced without coming down the geological scale later than the middle Cretaceous.

II. *Age of maximum relative predominance of each type.* The marine algæ, being the only vegetation, were supreme during the Cambrian and early Silurian. The maximum relative predominance of each of the other principal types was reached as follows: The Ferns in the Permian, the Equisetineæ and Lycopodineæ in the Carboniferous, the Cycadaceæ in the Lias or Oölite, the Coniferæ in the Wealden or Neocomian, the Monocotyledons in the Eocene, the monochlamydous Dicotyledons in the Cenomanian, the polypetalous Dicotyledons in the Miocene, and the gamopetalous Dicotyledons in the present living flora of the globe.

III. *Probable true period of origin and of maximum absolute development of each type.* Cellular Cryptogams of some kind probably lived in the Laurentian and account for the graphite beds and dark, carbonaceous matter of certain Archæan rocks. Being an heterogeneous group their later representatives belonged to entirely different families. If we include the Fungi the number of species is probably greater in the living flora than it was at any geological epoch. The Ferns, Equisetineæ, and Lycopodineæ probably all originated in the Lower Silurian and reached their absolute maximum in the Carboniferous. The Cycadaceæ may have originated as early as the Devonian. They must have attained their absolute as well as their relative maximum development in the middle Jurassic. The Coniferæ through their archaic form, the Cordaiteæ, began in the Lower Silurian. They attained their full maturity in the Cretaceous and are now on the decline. The Monocotyledons probably date back to the Lower Carboniferous or Devonian and reached their highest expression in the palms whose reign occupied the early Tertiary. These also are probably now waning. The Dicotyledons must have had their real origin in the lower Jura or upper Trias. Their absolute probably coincides with their relative development, the Apetalæ being now declining, the Polypetalæ about stationary, and the Gamapetalæ rapidly advancing.

[Diagrams showing the observed relative development and the probable origin and progress of each of the principal types of vegetation were employed to illustrate this paper.]

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THE TORSION OF LEAVES. By Prof. W. J. BEAL, Agricultural College, Mich.

[ABSTRACT.]

WHEN slightly wilted, *Chenopodium album* turns one edge of most leaves toward the sky, probably because the petiole is slightly compressed.

The leaves of both species of our *Typha* twist with the sun; the same is true of *Sparganium*. Most leaves of *Acorus Calamus* twist a little with the sun, especially toward the tip, though some twist in the opposite direction.

The leaves of *Fritillaria imperialis* twist with the sun. Those of *Allium porrum*, *Allium carinatum* twist well, and all against the sun. The leaves of *Allium cernuum* twist indifferently as to direction, and the twist is near the base where shaded. The leaves of several species of *Iris* twist against the sun, though on some leaves take both directions.

The ends of the leaves of *Gladiolus* all, or nearly all, twist against the sun. All of the above leaves are erect or nearly so. The leaves and bracts of *Liatris scariosa* are more or less horizontal and most twist with the sun, or what would be so, were the leaves tipped up erect. The true upper side of this leaf has the midrib most prominent and contains eighteen stomata to about twelve for the lower side. The ends of the leaf turn to the right as the main axis is held before us. The leaves of *Cyperaceæ*, so far as seen are without torsion.

The leaves of *Phleum pratense*, *Bromus secalinus*, Barley, Clawson wheat, *Triticum repens*, twist with the sun. The leaves of *Panicum capillare*, *Zizania aquatica* twist about as much one way as the other. The leaves of seedling oats, so far as seen, nearly all twist against the sun; those of *Setaria glauca* twist uniformly and well against the sun, while leaves of *Setaria verticillata*, *S. viridis*, *S. Italica* rarely twist any. The leaves of many other grasses were studied. The anatomy of leaves, the overlapping edge of the leaf sheath, the action of wind, sunshine and shade, were taken into account. In many cases, especially when young, the leaf twists most toward the tips; in some older leaves it is confined to the base. In some cases, most likely the sun has nothing to do with the torsion, but the excess of growth in the margins of the blade or petiole, especially when the midrib is not very stout.

Torsion aids slender leaves in maintaining an erect position. It helps expose different portions of the leaf to direct sunlight, at different times of the day. There is nothing more wonderful in the opposite direction assumed by leaves, than in the opposite course taken by stems of *Calystigia sepium*, all of which are good twiners.

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POLARITY OF LEAVES OF ERIGERON CANADENSE. By Prof. W. J. BEAL, Agricultural College, Mich.

[ABSTRACT.]

ON smaller stems of moderate growth, in a rather still place, well exposed to the sun, the slender leaves below the flowers show polarity; those on the north and south sides of the stem showing torsion, while those on the east and west side show little, if any.

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STOMATES ON SEEDS. By Prof. GEO. MACLOSKIE, College of New Jersey, Princeton, N. J.

[ABSTRACT.]

IT is usually said that seeds have no stomates, except of Canna.

I have shown that the seed of Magnolia have stomates, and those of *Lilium speciosum* have a few.

I now add to the list of seeds bearing stomates the following genera, Polygala, Hickory, Black walnut, Viola, Caulophyllum, Beech. Arisæma has a covering with stomates on its seeds, which is probably accessory to, and not really a coat of the seed.

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THE INFLUENCE OF CROSS FERTILIZATION UPON THE DEVELOPMENT OF THE STRAWBERRY. By Prof. WILLIAM R. LAZENBY, Ohio State University, Columbus, Ohio.

[ABSTRACT.]

FEW questions at the present time are exciting more interest among small fruit culturists than the one of cross fertilization. Whether the fecundation of one variety of plant by another of the

same or different species, affects the size, quality, and general appearance of the fruit so fertilized is a subject that has called forth no little discussion during the past year. Although much has been written upon this topic and various conjectures have been offered the writer is not aware that it has been made the subject of any well planned and carefully executed experiments.

In order to throw some light upon this important, yet wholly unsettled question, some investigations were conducted at the Ohio Experiment Station the past summer, a brief report of which is herewith given.

Some time before the period of blossoming of the strawberry it was decided to make a careful study of the different varieties with special reference to the following points:—

(1) To what extent are the so-called pistillate varieties stamen-bearing? (2) What is the comparative difference of pollen production in the bisexual or perfect forms? (3) What is the influence upon the fruit by fertilizing a well-marked pistillate variety by pollen from different and well characterized bisexual or perfect varieties? As the station had upwards of sixty varieties of the strawberry in a fruiting condition, all selected with care, true to name, and grown in plats sufficiently large to admit of reliable comparisons and estimates as to productiveness, quality, etc., the opportunities for conducting the investigations named above were exceedingly good.

In regard to the first two points we will only state that some abortive stamens were found in every one of the thirty-six so-called pistillate varieties that were examined. In every instance but one, grains of pollen were also discovered. These pollen grains, however, were often imperfect. In the bisexual or perfect varieties there was quite a marked variation as regards the number of stamens. Another interesting fact is that the quantity of pollen bears no definite relation to the number of stamens.

Some varieties, like the Sharpless, showing a comparatively large number of stamens produced a small amount of pollen, while in other varieties like the James Vick, the amount of pollen per blossom was much greater, although the average number of stamens was considerably less.

In order to answer the third question,— the influence upon the fruit of pollen from different varieties, a subject with which this paper has especially to deal,—the following plan was adopted: some

wooden boxes eighteen inches square and ten inches deep, without bottoms, were prepared. Before the strawberries blossomed a dozen or more of these boxes were placed at different points in a large plat of the Crescent seedling variety. Each box was placed so as to enclose some strong, healthy, vigorous plants. When put in position they were covered with a single plate of glass whitewashed, or with a light frame over which was stretched oiled cotton cloth. The plants thus enclosed were kept securely covered until they reached the period of full bloom. At this time pollen was conveyed to all blossoms that were in a suitable condition, all others being carefully removed, from the following well-marked bisexual varieties, viz.: Cumberland, Triumph, Sharpless, Charles Downing, and James Vick. Pollination was effected by simply removing some blossoms of the above named varieties when they were shedding their pollen, and rubbing them gently but thoroughly over the stigmas of the pistils of the Crescent. After this operation had been performed the plants were kept securely covered until it was seen that fertilization had taken place, or until the period of blossoming was over. In every case two boxes, as far removed as the limits of the plat, about one-eighth of an acre, would admit, were treated in the same way; that is, duplicate tests with each variety were made, and in two cases the plants in three boxes each were pollinized with the same variety.

In three boxes which were removed each from the others in the same manner the plants were kept covered, but no attempt at pollinization was made; the object being to find out whether, under those circumstances, self-fertilization would or would not take place. In these boxes no blossoms whatever were removed and they were left to themselves excepting an occasional examination to see if the plants remained healthy and vigorous. The results of these tests may be briefly stated as follows: In two of the three boxes where there was no attempt at artificial pollinization no fruit whatever was developed, although the plants blossomed naturally and appeared strong and vigorous. In the third box a number of imperfect berries were found upon the plants growing at one side, but no fruit whatever on the remaining plants.

It was noted during the course of the experiment that in one or two instances the covers of the boxes had been interfered with, and partially removed. It is more than probable that such had been the case with this box. In all of the boxes where the plants

were artificially pollinized, fertilization followed and a greater or less number of berries was the result.

Although somewhat imperfect, in every instance there was a marked resemblance in shape, size, color, and general appearance to the fruit of the male parent. All of the duplicate tests showed exactly the same results.

Owing to an early and long protracted drought strawberries grown in Central Ohio the past season were not nearly as large or perfect as they usually are. The same cause affected the cross-bred berries, yet, despite this, the characteristics of the male parent were plainly evident in each case. So strongly did they predominate that there was little or no resemblance to the fruit of the female parent. No one could have named any one of the four cross-bred samples as Crescents, while every one acquainted with the varieties from which the pollen was taken could readily identify the fruit it had fertilized as the same variety. Where the pollen of the Cumberland Triumph was used the color was very light and the berries exceedingly soft. Those fertilized with the pollen of the James Vick were small but very firm and remarkably perfect in outline. The cross with the Charles Downing showed marked resemblance in shape, color, and consistency to this well known variety. It showed also the characteristic gloss of this fruit. Where the Sharpless was used as the male parent the berries were large and irregular, the fruit of this cross being much more imperfect than that of any other cross. Thus far we have only spoken of the effect produced by cross-fertilizing one well known pistillate variety of the strawberry, the Crescent.

A further test was made in the same manner by pollinizing a comparatively new pistillate variety, the Manchester, with the Sharpless and with the James Vick, two of the four varieties used to fertilize the Crescent. The results obtained were precisely similar to those already described. The Manchester fertilized by the Sharpless produced large berries resembling the Sharpless, and possessing few of the characteristics of the Manchester. When artificially pollinized by the James Vick, the Manchester produced a small, firm, perfect, and regular berry like that of the male parent.

In regard to the effect of cross-fertilization upon the flavor we cannot speak as confidently as of the characteristics just now named. Being anxious to save the seed this point was not

thoroughly tested. In our judgment, based upon a careful test of only a few berries, the difference here was just as pronounced as it was in the size, shape, and color of the fruit.

In addition to the tests already reported the following were made.

Four boxes like those already described were placed over plants of the following bisexual or perfect varieties, viz.: Iron Clad, Finch's Prolific, Charles Downing and Sharpless. These were simply covered during the whole period of blossoming. In each case fair samples of fruit were produced, differing in no respect from the fruit of the same variety on plants growing under natural conditions. Four more boxes were placed over the following pistillate varieties, viz.: Windsor Chief, Gypsy, Photo, and Huddleston's Favorite. The result was no fruit whatever, although each of these varieties were fairly productive where the plants were not thus covered. Two questions naturally arise: (1) If the influence of the pollen is as marked as our experiments indicate, why has it not been more generally observed? That the same variety of strawberry did often present great differences has frequently been noticed, but has usually been referred to the influence of the soil, fertilizers, season, climate, etc.

Several years ago I observed that the Crescent grown in a certain garden and fertilized by the Wilson was a very different berry from the Crescent grown in another garden and fertilized by the Charles Downing. This difference was then, however, all attributed to other causes.

(2) If the effect of cross-fertilization is as marked in every instance as in the cases described how do our well known varieties preserve their characteristics? In reply to this question we must remember: (1) That pistillate varieties have not been so long or generally cultivated as bisexual or perfect varieties. (2) That many of the so-called pistillate varieties produce more or less pollen. (3) As a rule quite a number of varieties of the strawberry are grown in close proximity, and the plants are probably fertilized by pollen from all the stamen-bearing varieties. Hence the influence of one may be neutralized by that of another. In all our sixty varieties growing side by side, about two-thirds of which are pistillate, the characteristics of the fruit of each were preserved, and no one could tell by an examination of the fruit alone, by what pollen any one variety had been fertilized. Yet in every case where a variety was known to be fertilized by the pollen from just one other variety the influence was marked and decisive.

INFLUENCE OF INSOLATION UPON VEGETATION. By Dr. E. LEWIS STURTEVANT, Geneva, N. Y.

THE action of temperature and light upon vegetation is to advance growth and form plant product under the guidance of the life or vitality of the plant. Thermometric data seem insufficient alone to explain the phenomena of assimilation. The difficulties of an investigation of such complexity arise from insufficiency of records, as well as from the individuality of the seed, and the varied temperaments of different observers. At the New York Agricultural Experiment Station, Geneva, records of the maxima and minima thermometers have been kept, and of the temperature of the soil at 1 in., 3 in., 6 in., 9 in., and 12 in. in depth, and as well of the planting, germination, blooming, etc., of individual plants. From these data the present paper is prepared, which gives only the relations of the plant maturation to the observed temperatures.

For our purposes the first plant which vegetated, bloomed, or became ripe is taken; another course would have involved a greater uncertainty. Thus in 128 varieties of maize, four hills of each, the average variation between the blooming of the first and last hill was 4.92 days, the extremes 0 and 19 days. Properly classified these differences were as follows:

| | Average difference, days. | Greatest difference, days. |
|---|---|---|
| 46 Sweet corn varieties, | 4.93 | 19 |
| 26 Flint corn varieties, | 5.46 | 10 |
| 15 Dent " " | 4.87 | 10 |
| 16 Soft " " | 5.31 | 10 |
| 5 Pod " " | 1.60 | 3 |
| 6 Pop " " | 2.83 | 4 |
| 14 Miscellaneous, | 5.57 | 15 |
| 128 | 4.92 | |

As the temperature of the soil, as well as that of the air influences growth, we have in addition to the mean of the maxima and minima, calculated the mean of the air and soil readings. Sachs gives the lowest temperatures for germination for maize at 49.°1 F.,[1] Koppen at 49°.2 F. We may assume, therefore, for maize that growth does not take place much below 50° F., and can form a set of figures which shall represent temperatures above 50° for maize, and in like manner above 44° for the pea.

[1] At a temperature of 37° to 42° F., the Chester Co. Mammoth corn germinated in 430 hours during a trial at the New York Agricultural Experiment Stationending April 4, 1885; the Waushakum, in 460 hours.

| | | | | Sum of daily mean temperatures between vegetation and bloom. | | |
|---|---|---|---|---|---|---|
| | | | | Calculated on air temperature. | | Calculated on air and soil to 1 foot. |
| SWEET CORN. | Planted. | Vegetated. | Bloomed. | Total. | Above 50°. | Above 50°. |
| Crosby's Early, | May 16, 1883 | May 28 | July 21 | 3571° | 871° | 931° |
| " " | " 19, 1884 | " 26 | " " | 3620° | 820° | 943° |
| Dolly Dutton, | " 16, 1883 | " 28 | " 16 | 3241° | 791° | 910° |
| " " | " 19, 1884 | " 26 | " 13 | 3121° | 721° | 809° |
| Egyptian, | " 16, 1883 | " 28 | Aug. 6 | 4635° | 1185° | 1191° |
| " | " 19, 1884 | " 26 | July 28 | 4050° | 900° | 1073° |
| Stowell's Evergreen, | " 16, 1883 | " 28 | Aug. 2 | 4372° | 1072° | 1127° |
| " " | " 19, 1884 | " 27 | " 3 | 4429° | 1029° | 1167° |
| FLINT CORN. | | | | | | |
| Forty Days, | " 16, 1883 | " 28 | July 23 | 3727° | 927° | 954° |
| " " | " 19, 1884 | " 26 | " 10 | 2929° | 679° | 755° |
| King Philip, | " 16, 1883 | " 28 | " 23 | 3777° | 927° | 970° |
| " " | " 19, 1884 | " 26 | " 22 | 3726° | 876° | 960° |
| Rural Thoroughbred, | " 16, 1883 | " 28 | Aug. 8 | 4779° | 1179° | 1220° |
| " " | " 19, 1884 | " 26 | " 4 | 4557° | 1057° | 1200° |
| Waushakum, | " 16, 1883 | " 28 | July 23 | 3727° | 927° | 970° |
| " | " 19, 1884 | " 26 | " 21 | 3659° | 859° | 943° |
| DENT CORN. | | | | | | |
| Adams Early, | " 16, 1883 | " 28 | " 17 | 3328° | 828° | 980° |
| " " | " 19, 1884 | " 27 | " 26 | 3851° | 851° | 1026° |
| Benton, | " 16, 1883 | " 28 | Aug. 1 | 4326° | 1076° | 1110° |
| " | " 19, 1884 | " 27 | July 28 | 4048° | 948° | 1063° |
| Blount's Prolific, | " 16, 1883 | " 28 | Aug. 1 | 4326° | 1076° | 1110° |
| " " | " 19, 1884 | " 28 | " 14 | 5148° | 1248° | 1361° |
| Chester Co. Mammoth, | " 16, 1883 | " 28 | " 10 | 5117° | 1417° | 1255° |
| " " " | " 19, 1884 | " 26 | " 14 | 5268° | 1268° | 1384° |
| Sibley's Pride of the North, | " 16, 1883 | " 28 | July 22 | 3657° | 907° | 949° |
| " " " " " | " 19, 1884 | " 27 | " 26 | 3979° | 979° | 1026° |

| Pea. | Planted. | Vegetated. | Ripe. | Sum of daily mean temperatures between vegetation and ripeness. Calculated on air temperatures. Total. | Calculated on air temperatures. Above 44°. | Calculated on air and soil to 1 foot. Total. | Calculated on air and soil to 1 foot. Above 44°. |
|---|---|---|---|---|---|---|---|
| American Wonder, | April 21, 1883 | May 9 | July 10 | 3822° | 1214° | 4001° | 1273° |
| " " | May 12, 1883 | " 26 | " 17 | 3444° | 1156° | 3575° | 1287° |
| " " | April 18, 1884 | " 9 | " 7 | 3678° | 1062° | 3745° | 1149° |
| Champion of England, | " 21, 1883 | " 8 | " 19 | 4487° | 1319° | 4679° | 1511° |
| " " " | May 12, 1883 | " 28 | Aug. 1 | 4458° | 1466° | 4547° | 1555° |
| " " " | April 28, 1884 | " 8 | July 21 | 4605° | 1347° | 4711° | 1453° |
| Kentish Invicta, | " 21, 1883 | " 7 | " 16 | 4330° | 1250° | 4518° | 1438° |
| " " | May 12, 1883 | " 25 | " 24 | 3977° | 1337° | 4700° | 2060° |
| " " | April 28, 1884 | " 9 | " 2 | 3317° | 941° | 3381° | 1005° |
| McLean's Advancer, | " 21, 1883 | " 8 | " 17 | 4345° | 1265° | 4538° | 1458° |
| " " | May 12, 1883 | " 25 | " 28 | 4235° | 1410° | 4279° | 1463° |
| " " | April 28, 1884 | " 9 | " 28 | 4965° | 1445° | 5161° | 1641° |
| Premium Gem, | " 21, 1883 | " 8 | " 10 | 3876° | 1104° | 4054° | 1282° |
| " " | May 12, 1883 | " 25 | " 18 | 3573° | 1197° | 3531° | 1155° |
| " " | April 18, 1884 | " 9 | " 14 | 4060° | 1156° | 4219° | 1315° |
| Telephone, | " 21, 1883 | " 8 | " 17 | 4345° | 1265° | 4535° | 1458° |
| " | May 12, 1883 | " 25 | Aug. 6 | 4827° | 1615° | 4878° | 1666° |
| " | April 28, 1884 | " 9 | July 21 | 4557° | 1345° | 4662° | 1450° |

The average of the two years' determinations shows the following figures:

| | Sum of daily mean temperatures between vegetation and bloom. | | |
|---|---|---|---|
| | Calculated on air temperature. | | Calculated on air and soil to 1 foot. |
| SWEET CORN. | Total. | Above 50°. | Above 50°. |
| Crosby's Early, | 3595° | 845° | 937° |
| Dolly Dutton, | 3181° | 756° | 859° |
| Egyptian, | 4342° | 1042° | 1182° |
| Stowell's Evergreen, | 4400° | 1050° | 1147° |
| FLINT CORN. | | | |
| Forty Days, | 3328° | 803° | 854° |
| King Philip, | 3751° | 901° | 965° |
| Rural Thoroughbred, | 4668° | 1118° | 1210° |
| Wanshakum, | 3698° | 893° | 956° |
| DENT CORN. | | | |
| Adams Early, | 3589° | 839° | 978° |
| Benton, | 4187° | 1012° | 1086° |
| Blount's Prolific, | 4737° | 1162° | 1235° |
| Chester Co. Mammoth, | 5193° | 1342° | 1319° |
| Sibley's Pride of the North, | 3818° | 943° | 987° |

| | Sum of daily mean temperatures between vegetation and ripeness. | | | |
|---|---|---|---|---|
| | Calculated on air temperature. | | Calculated on air and soil to 1 foot | |
| PEA. | Total. | Above 44°. | Total. | Above 44°. |
| American Wonder, | 3648° | 1150° | 3773° | 1236° |
| Champion of England, | 4516° | 1377° | 4645° | 1506° |
| Kentish Invicta, | 3874° | 1176° | 4199° | 1501° |
| McLean's Advancer, | 4515° | 1376° | 4659° | 1520° |
| Premium Gem, | 3836° | 1152° | 3934° | 1250° |
| Telephone, | 4576° | 1408° | 4692° | 1524° |

That these figures show what in the present state of my knowledge I may call eccentricities, seems evident; they also show a variety difference of considerable extent, and justify the assertion that until investigators give the vernacular identifying name to a variety used, instead of the specific name, there can be but little wonder at the difference of results claimed by different observers. It is probable that actinism has an influence scarcely second to temperature.

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A BOTANICAL STUDY OF THE MITE-GALL FOUND ON THE PETIOLE OF JUGLANS NIGRA, KNOWN AS ERINEUM ANOMALUM SCHW. By Miss LILLIE J. MARTIN, High School, Indianapolis, Ind.

[ABSTRACT.]

I. A general survey of the gall as to position, number, effect on petiole, general appearance, etc., etc.

II. A description and comparison of the microscopical appearance of the gall and normal petiole.

*a.* The walnut petiole resembles that of many other dicotyledonous plants in the arrangement of the fibro-vascular bundles, the parenchyma above the bundles, the epidermis and the clustered and glandular hairs.

*b.* The fibro-vascular bundles in the gall are much bent and folded; trachedes have replaced the tracheary vessels, the wood and bast are not increased in amount but are more widely distributed. The parenchyma above is composed of larger cells than those in the parenchyma of the normal petiole and the cells contain much more protoplasm. The epidermal cells are thin-walled, irregular in shape, large, in fact quite unlike normal epidermal cells. The gall hairs seem to be outgrowths, or rather, continuations of the epidermal cells and not true trichomes. They are larger than the hairs of the normal petiole and quite unlike them in shape and contents. When the purplish-red coloring matter which they contain is removed they are found to contain a brown granular substance.

III. Suggestions as to development. These are founded on a comparison of the gall with the normal petiole.

*a.* The gall must have started very early in the growth of the petiole, for no vestiges of normal tissues are found nor does the resemblance between the corresponding parts of the gall and normal petiole suggest that the first is a modification of the second.

*b.* The development was inward doubtless. The eggs are on the outside and there is no indication that the tissues have been pierced by the ovipositor.

*c.* Reference is made to the value of the various modifications to the mite.

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THE ADVENTITIOUS INFLORESCENCE OF CUSCUTA GLOMERATA. By Prof. C. E. BESSEY, Lincoln, Neb.

[ABSTRACT.]

CLOSE examination of the young plant of *Cuscuta glomerata* shows that the inflorescence is developed from numerous crowded adventitious buds, and not by the repeated branching of axillary flowering branches, as is commonly stated.

UTRICULARIA VULGARIS WITH YOUNG TELEOSTEAN FISHES ENTRAPPED IN THE BLADDER TRAPS OF THAT PLANT. By H. N. MOSELEY, Professor of Anatomy, University of Oxford, England.

[ABSTRACT.]

SPECIMENS of the plant with young fishes caught in its bladder traps were exhibited.

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ON THE EXTINCTION OF SPECIES. By Prof. THOMAS MEEHAN, Germantown, Pa.

[ABSTRACT.]

THE author refers to the statement of Mr. Darwin's *Origin of Species*, p. 279, "that if we ask ourselves why this or that species is rare, we answer that something is unfavorable in its conditions of life, but what that something is, we can hardly ever tell." In this paper the author shows that dichogamy and agencies for cross-fertilization in flowers, are evidently to be classed among the unfavorable conditions of life and are doubtless part of a natural law providing for the final extinction of species.

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OBJECTIONS TO SOME COMMONLY ACCEPTED VIEWS OF HEREDITY. By Prof. ALPHEUS HYATT, Curator Society Natural History, Boston, Mass.

[ABSTRACT.]

HEREDITY has no need of the gemmule hypothesis or pangenesis, but can be equally well understood upon the supposition that the nuclei of cells are the immediate agents of the transmission of characteristics. The author then presented the case of a man in Maine who resembled the mother on one side and the father on the other, as an illustration of his theory and contested Prof. Brooks' position with regard to heredity.

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FERTILITY IN HYBRIDIZATION. By Hon. ROBERT BARNWELL ROOSEVELT, New York, N. Y.

BEFORE entering into the gist of the matter implied by the title of this paper it may be wise to determine the true meaning of the word "hybridization." "Rare old Ben" Jonson remarks of a young lady in one of his plays that, " she's wild Irish born, sir, and a hybride." Now if that is to be the acceptation of the word "hybrid" the end of this article is reached before it is fairly commenced, for that fertility exists among the "wild Irish," and to no small degree, no one doubts who has seen the "beautiful plenty" of children in and around the cabins of "old Ireland." Indeed, under that construction, our entire American nation might be called a race of hybrids for are we not the intermixture of representatives of the sons and daughters of the entire earth, whether born on the green sod of the "Gem of the Sea" or under the tropical sun of Africa, the "what is its," of Central America or the moon-eyed followers of Confucius. Fortunately however we discover a charming diversity of opinion herein as with the case of more than one other scientific problem and find a doubt and disagreement as to the very meaning and derivation of the term hybrid. By some learned authorities it is derived from "*hybrida*," Latin for monstrosity, an outrage upon or insult to nature, order, propriety and beauty. But other equally scientific writers assure us that the word is derived from the Greek ὑβρὶδ which means superior, above, improved. It is unnecessary to observe how well that definition would apply to the American nation and even "rare old Ben" may have had this interpretation in view when he printed that line as he spelled the word with an "e," making his wild Irish girl a "high bride." Something of this superiority I hope may be found in the creatures to which I am about to refer although they will at the same time come under the more common definition of mongrel or cross between different races or families. The term race or family is not used in a purely accurate scientific sense, for hybridization even with plants has been limited to species nearly allied. With them specifical hybridism may be said not to be unusual even in a state of nature but with living creatures it is mostly if not entirely forced, or brought about through the interference of man. The union of the wild bore with the domestic sow and of the wolf and the dog which

are more or less natural are not hybridization in the true sense of the word as the species which have thus united are admitted to be identical in their origin and only modified by domestication. The case of the lion with the tigress is too rare to be considered and among animals we are brought practically to that of the horse and the jackass which produces our common and useful mule. That the mule is the superior of its progenitors on both sides will hardly be admitted, but both the mule and the janette with a few rare exceptions have proved themselves sterile. The law of nature throughout all terrestrial life seems to be that no mongrel should procreate, no hybrid create a new race or species, but that like the fairies when they died they were to die out of existence leaving no heirs to their fame or name. This rule holds as to the *mammalia* without an exception and it is only when we come to another and perhaps inferior order of life that we have lately found modifications of it.

When fish-culture grew from mere individual and occasional effort into a science and system, one of the possibilities which suggested itself to ingenious minds was the crossing of different species. As the entire operation of producing fertility was artificial, there was no sexual repugnance against intercourse to be overcome, the eggs of any species of female being stripped from her could be fertilized by the milt from the male of any other species. That is, the spermatozoal embryos could be brought into contact whether fertility followed or not which at first was doubtful. The crosses made in this way under the New York state fishery commission have been very numerous and in some instances quite unnatural and the results have proved equally surprising and unexpected. The first cross was that of the California salmon, *Salmo quinnat* and the brook trout, *Salmo fontinalis*. This was in the year 1876 and the species being so closely allied fertility of the eggs and vitality of the young could almost be predicted with certainty. Then came the cross of the salmon or lake trout, *Salmo confinis* with the brook trout, then the California trout, the *Salmo iridea* and the brook trout, and thereafter the entire range of the salmon and trout families, as far as they were within the reach of the operators, were combined in many and curious proportions. Outside of that, even more remarkable attempts were made such as the union of the striped bass and shad, which came about by accident, utilized by intelligence. A ripe female striped

bass or rock fish *Labrax lineatus* being caught in the nets during the course of the operations of the shad hatchery on the Hudson River, and there being no male bass to be obtained, the eggs were taken and brought into contact with the milt of the male shad, *Alosa sapidissima*. Then these eggs were placed in a box entirely by themselves and every precaution was taken to make the experiment perfect. The eggs hatched; of that there is no question, but whether the product was the result from that impregnation or whether it was reached by the chance contact with floating seminal animalcules from bass, or whether the young lived after they were hatched, may be regarded as still open for consideration. As there was no possibility of keeping the fry in confinement the experiment goes no farther than opening the field of study and research.

Fish do not attain sexual maturity as soon as is generally supposed, and in confinement it is probable that this period is even more prolonged. The earliest hybrids to mature their *ova* were the cross between the male California salmon and the female brook trout. This took place in the year 1879. They not only became gravid but ascended the spawning races as naturally as those of either distinct species and evidently with the intention of procreating. But as they deposited no eggs and did not appear to mate, an examination of them was made and it was ascertained that they were all of one sex, the entire family being females. To remedy this a number of male spawning brook trout were admitted to the same race-way; these promptly paired with the half-breed lady fish selecting their wives as readily as they would from their own species, but although they made all the preliminary preparations no results appeared from their union. The nests had been constructed but no eggs had been deposited in them. A further examination proved that the eggs were too large to pass the ovarian opening. When they were extruded by force as in the stripping process the shells were crushed and a few which were obtained by the use of the knife, a sort of modified Cæsarean operation, and were brought into contact with the milt of the trout, failed to impregnate and perished. This experiment led to the conclusion that, where the male was much the larger fish, the *ova* might be too large for extrusion and also that possibly under certain contingencies all of one hatching might be of a single sex. In all subsequent operations however the proportion of each sex has been about equal. Some of these

females of the first batch of hybrids which never matured eggs, although they had not the honor of parentage, are still living, grizzled and gaunt like the proverbial old maids of the jocose story-writers, but they have never repeated the attempt to perpetuate their species, one abortive effort in that direction seeming to exhaust their aspirations for maternity.

The cross of the male brook trout and the female salmon trout, the *Salmo fontinalis* with the *Salmo confinis*, matured *ova* in October, 1880. There were about 72,000 eggs cast which hatched as readily as those of either parent although it was found that a larger percentage of them could be impregnated with the milt of the male brook trout than with the milt of their own kind. The percentage of fertility was good and the young proved to be perfectly healthy and as able to stand the struggle for existence as any of their brethren of pure strain. Upon this discovery rested the possibility of a great future for fish-culture. There were qualities in each of these species which it was exceedingly desirable to combine. The *Salmo confinis* grow to a far greater size than the *Salmo fontinalis;* they are hardier, easier to hatch and handle and more able to take care of themselves, while the brook trout are the more delicate in flavor, the more admirable as a sporting fish and will take the fly in fly-fishing, which is the crowning virtue in a fish from the angler's point of view. In the hope of reaching such a result this process of interbreeding has been kept up regularly from its inception. At the first cross one-half of the salmon trout was eliminated, their young impregnated with the milt of the male brook trout left only a quarter of the coarser parent, and then came those which were seven-eighths brook trout to one-eighth salmon trout which is as far as we have got at the present time. The young of each of these generations show the effects of the cross just as we have witnessed the occasional bleaching out process in this country between the children of Africa and those of colder climates. The first in descent had none of the carmine specks which are the distinguishing feature of the "speckled trout" of our brooks. In the second generation the spots began to appear, and in the last they are distinctly visible although fewer in number than in the trout of *Sangre Azul*. Of their habits and qualities other than their growth and their flavor on the table we have had as yet no opportunity to judge. Those of the first cross have been eaten on several occasions by epicurean judges and were pronounced excel-

lent, fully up to the reputation of either of the parents. In the year 1883 there were distributed to the brooks of the state 45,300 hybrid fry which were one-half salmon trout and one-half brook trout, and in 1884 a second planting of 79,000 three quarter brook trout was made. Neither of these has been in the streams long enough to determine how they will act nor how they will get on when left to shift for themselves. They may go back like the fancy pigeons to their original breed or they may remain permanent or even branch out into infinite modifications. The fact remains that in this artificial way a new breed has been established, whether it is designated as a new species or not, which can be maintained by manual perpetuation forever, and another conclusion is proved that hybridism is not necessarily another word for sterility.

That the young will spawn naturally is probable if not certain in view of their procreative instincts when in confinement and that they will live and grow is fully ascertained. They are in no wise like the monstrosities with two heads or two bodies which occasionally appear and that die as soon as they reach the feeding age after the umbilical sac is absorbed. The first which were deposited in wild waters were found in six months to have attained a growth of four and a half inches in length, equal to the growth of a brook trout in the same water for an entire year. These operations have been conducted on a sufficiently extensive scale to justify the deduction of some quite positive conclusions and have been attempted with several quite incongruous species. The first cross as we have seen was that of the *Salmo quinnat* with the *Salmo fontinalis;* the second, the *Salmo fontinalis* and the *Salmo confinis*, then the salmon trout, *Salmo confinis*, was bred with the white fish, the *Coregonus albus*, the brook trout with the fresh water herring, *Salmo clupeiformis*, the brook trout and the California trout, *Salmo iridea*, the shad, *Alosa sapidissima* with the striped bass, *Labrax lineatus*, and the shad with the salt water herring. There are at present at the New York hatchery 10,000 breeding hybrid fish of the various modifications and during the year 1883–4 hundreds of thousands of fry were hatched. The cross of the shad with the salt water herring appears to have lived as the fishermen have taken them so frequently as to designate them as "Seth Green's shad," it is possible however that they are all males as those which have been examined seem to be so. While mentioning the name of the putative father of the "herring-shad," I cannot withhold the

well deserved meed of praise to Mr. Seth Green and his brother Monroe A. Green for the intelligent and earnest interest they have taken in these experiments.

In these operations we have not only made interesting discoveries which promise benefit to the consumers and catchers of fish, but we have reserved for the world of science that I have seen so fully represented at this meeting of the Association, a pleasure which of all others they most enjoy, the opportunity of inventing long, learned and distinguishing names for the product of our efforts. It will be their special duty to tell the world just how the mixed up babies should be termed, whether the young of the brook trout unto the third and the fourth generation is to be the *Salmo confinis fontinalis* or *Salmo fontinalis confinis* and whether the *fontinalis* is to be duplicated like treble x ale in the succeeding generations, and how they will distinguish such an "odd fish" as that of the intermingling of the *Alosa sapidissima* one of the *Malacopterygii* or soft-finned fishes with the *Labrax lineatus*, a prominent member of the *Acanthopterygii* or spine-finned fishes. As the trout has married the salmon and the shad has united its fate with the herring and the white-fish has taken in unholy, because artificial, wedlock the brook trout, it would seem to be impossible to determine where the limits of hybridism in fish culture may yet be found.

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THE COMPARATIVE LONGEVITY OF THE SEXES. By Mrs. A. B. BLACKWELL, Elizabeth, New Jersey.

[ABSTRACT.]

THIS paper presents a new grouping of statistics condensed from some of the earlier as well as more recent census returns of our own and other countries.

The following conclusions are reached:—

1. All ages included, the sexes are normally about equal in numbers. The old countries have an excess of women, the new of men. Statistics of emigration for a term of years, added to the population of the country emigrated from, or subtracted from that emigrated to, confirm this law. So do all fair aggregates giving a due proportion of older and newer states. The larger the aggregates, the more marked becomes the approximate equality.

2. The sexes are not equal in numbers at the same ages respectively; except during a probably more or less variable period towards middle life. At all the early ages, males are habitually in excess. At all the late ages females are habitually in excess, and the larger the aggregate at the same ages, the greater is the numerical inequality.

3. The present state of statistical science does not enable us to determine very accurately at what age the sexes are equal numerically. The period lies somewhere in early middle life, certainly between fifteen and thirty-five, but any estimate must discount an obviously unusual imperfection of the records at about those ages. Probably also the period itself varies with varying conditions and can be only a movable average.

4. The younger the age compared, the larger is the relative proportion of males. More boys are born, but the excess diminishes from birth onwards in something like a regular gradation until the sexes reach numerical equality; then an excess on the female side increases progressively, though much more rapidly in proportion to the numbers compared, to the end of life. Life has a longer average to the female than to the male. Records of births and of deaths confirm the direct count of numbers in all these particulars.

5. The relative proportion of boys and girls is approximately the same in all countries. A large total excess either of males or of females has very little effect on these ratios. The ratio of adult males and females, at specified ages, is directly affected by the relative proportions of the sexes in the total population.

6. The Mortality Tables indicate that girls, like boys, bear hereditary taints and die in consequence at any period of life; and yet that at every period of life the girl has the slightly better chance of survival.

7. There are exclusive feminine ailments which cause death by the thousands in every large community and also in most countries women are more subject to all that class of diseases which, like consumption, arise oftener from impure air than from great exposure. This extra fatality to women, occurring more generally in middle life, is largely an offset to extra male risks incident to business enterprises, wars, and hazards in general, incurred at about corresponding ages. Hence, distinctively during a considerable period of middle life there is approximate equality of numbers between the sexes in death rates as also in life ratios.

8. The general facts above stated have long been known. Every

census teems with them. Life Insurance and Annuity Tables have discounted them; and yet their mutual relation and cumulative significance seem to have escaped attention. They have been treated as results probably incidental and temporary, arising from unknown complex, probably highly variable causes. But the approximate uniformity of returns gathered from most widely various peoples, half savage and civilized, during a long term of years, points us to constitutional causes beyond the control of ordinary contingencies. Nature's constant method of maintaining a complicated numerical balance is Nature working in accordance with established law.

There are two possible explanations of the fact:—

1. The hereditary results of male hardships, hazards or excesses, transmitted to the same sex only, have been so great that the average of life to that sex has become grievously shortened thereby.

2. The feminine constitution, being, much beyond the male constitution, differentiated in the two classes of organic functions distinguished as individual and reproductive, together with the earlier limitation of the latter, the female gains thereby a greater reversionary source of energy towards the close of life; as also a larger available reserve force, which, in case of disease, may be called into vicarious action at all ages. The increased longevity thus resulting, though primarily affecting females only, if inherited by both sexes, would tend to the extension of the average life of the race. It would work very much as the increase of size and strength is supposed to have arisen through the male line of descent.

But let the explanation be what it may, the tables exhibited will verify the alleged facts. [Copies of these tables can be had by addressing the author.]

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RESEARCHES ON GROWTH AND DEATH. By Dr. CHARLES SEDGWICK MINOT, Harvard Medical School, Boston, Mass.

[ABSTRACT.]

THE following investigations have for their purpose, to contribute to the solution of the problem of the effects of age upon organisms, and the manner in which age causes death. I deal first with the

problem of growth, the most obvious of the effects of age, and present the results of my experiments covering over three years and including nearly 10,000 measurements of the weights of growing animals, chiefly Guinea pigs. These statistics enable us to gain a new insight into the matter because they cover the whole period from birth to maturity, thus enabling us to calculate the rate of growth for the entire post-fœtal interval. Hitherto the actual increments of growth have been compared directly with one another, but if we adopt a new and correct method of comparison, we reach a conclusion of, I believe, great importance, viz. :—that the rate of growth steadily diminishes from birth onward, so that the loss of power begins at once and continues until it culminates in death. The new method consists in calculating the average daily increment during a given interval, in the per cent of the weight at the beginning of that interval. The series of percentages thus obtained may be legitimately compared with one another and yield the result above given. Another manner of demonstrating the same relation of potential power at different ages, is to calculate by interpolation, the length of time necessary to add ten per cent to the weight. It is found that the older the animal is, the longer it requires to increase ten per cent.

My measurements by various methods of grouping, throw much light on the loss of weight in some animals immediately after birth, on the relative growth of males and females, the effect of reproduction on growth (which are the reverse of what Herbert Spencer has asserted), the dependence of the size, number, sex and weight of the young upon the age of the mother, season of the year, the determining causes of sex, etc. These subjects will all be treated statistically.

I wish to discuss particularly the bearing of the results obtained on the general theory of senescence, and to criticise from the new standpoint the views on death recently emitted by Weissmann, Goette, Bütschli, *et al.* In this connection it will be necessary to attack the current conceptions of animal individuality. In the course of this discussion I shall show that the results obtained in regard to the growth and other phases of development of man agree closely with the deductions from my own experiments.

In conclusion I wish to refer briefly to the bearing of our present knowledge of senescence upon the theory of life and the relation of life to a material substratum.

BIOLOGICAL PROBLEMS. By Dr. CHARLES SEDGWICK MINOT, Harvard Medical School, Boston, Mass.

[ABSTRACT.]

IT is wished to present certain considerations in regard to some general problems, which although they hardly cohere naturally, yet may be conveniently considered at once.

1. *Linnæan System of Nomenclature.* The question is—whether it is desirable to return in some form to the use of the Linnæan system, which gradually has been replaced by an entirely new binomial system. We have retained the form, while we have rejected the principle of nomenclature introduced by Linnæus, who used the generic name in a wide sense to indicate the kind. The whole number of generic names was small and easily acquired, so that the combination of the two names gave a general and a special designation. At present genera are also special groups and approximate to a single species so far has the subdivision gone. It results that the name we call generic is no longer generic in value. Of the two extremes the Linnæan is, I believe, preferable. I expect to see a large number of genera set aside hereafter.

2. *Scientific determination of species.* The present method of determining the type of a species is thoroughly unscientific, because it is based upon the history of scientific literature, and not upon observation of nature. I believe that species will have to be all redetermined and the true or actual natural type settled by a statistical study of the variations of each species. It is well known that varieties occur in the greatest number about the mean, and the greater the departure of any variety from the mean the more rarely it occurs. It is evident therefore that the central type of any given set of varieties, *i. e.* of a species, is that variety which occurs most frequently—hence the type must be determined statistically, Q. E. D.

3. *Individuality.* Much confusion exists on the subject of individuality, which is tacitly assumed to be a quality of a specific nature, or in other words that all individuals have as such, a property in common. It is evident that this results from a deficiency of clearness in thought, and that individuals are not homologous always,—any more than wings are. The only two fixed units are first, cells, second the whole series of generations of cells from a single ovum, a cell-cycle. An individual may be almost any fractional

part of a cell-cycle; roughly speaking the higher the organism the fewer the number of individuals it comprises, or in other words the larger the number of cells in each individual. It would not be necessary to refer at all to the nature of individuality were it not for the frequency of misconceptions of the subject shown in the writings of the majority of writers who touch upon it.

4. *Homologies of the ovum.* I have been led to the hypothesis that the ovum is homologous with an encysted protozoon, the zona radiata or pellucida being the equivalent of the capsule or cyst of the protozoon, and the contents also homologous. I propose to state briefly the reasons which support this hypothesis.

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VESICULÆ SEMINALES OF THE GUINEA-PIG. By Dr. CHARLES SEDGWICK MINOT, Harvard Medical School, Boston, Mass.

[ABSTRACT.]

THE *Vesiculæ seminales* of the guinea-pig are two long, tapering cæca suspended by a mesentery from the abdominal wall. They contain no spermatozoa, but only a whitish, sticky, granular secretion. The inner surface is lined by a simple, cylinder epithelium thrown up into irregular folds, a most unusual arrangement among vertebrates, for the folds are formed by the epithelium with only an extremely thin supporting lamina of connective tissue. There is a thin mucosa, and a well developed external muscular coat of circular fibres. From the structure of the vesiculæ, it is probable that they are morphologically diverticula of the *vas deferens*, but not of the *ductus ejaculatorius*.

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ON THE SKIN OF INSECTS. By Dr. CHARLES SEDGWICK MINOT, Harvard Medical School, Boston, Mass.

[ABSTRACT.]

THE skin of insects consists of a cuticula, a layer of epithelium and an underlying sheet of connective tissue. The epithelium is

homologous with the epidermis of other animals and ought to be so called instead of hypodermis, the usual entomological term. The usual application of "epidermis" to designate the cuticula or external crust is entirely unjustifiable. The term dermis ought to be applied to the connective tissue, as it is homologous with the dermis of vertebrates.

The cuticula in caterpillars has interesting features, not yet described. Two very distinct strata are distinguishable: a thick one constituting nearly the whole thickness of the cuticula, and an exceedingly thin, superficial one, which alone is pigmented and ornamented. The pigment is distributed in beautiful microscopic patterns, which are characteristic for each of the twenty species investigated. (The author will exhibit preparations to show these markings, and will describe them.)

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THE DYNAMICS OF THE INSECT-CRUST. By Prof. GEORGE MACLOSKIE, College of New Jersey, Princeton, N. J.

[ABSTRACT.]

GENERAL description of the chitinous skeleton and its various outgrowths and ingrowths, its thickenings and sculpturing.

Comparison of the tracheæ and salivary-ducts. Structure of tracheæ, as having spiral crenulations, hitherto misunderstood and supposed to be threads.

Action of tracheæ, for transmitting gases directly to the tissues (and not by the intervention of blood).

The tracheæ are not directly controlled by muscles; their action depends on the successive production of a partial vacuum and condensation of air around them; this depending on the pulsation of the abdominal walls of the insect; these walls richly supplied with muscles.

Similarly the extension and retraction of wings, proboscis and other organs, are, in the first instance, exclusively mechanical, and only in a remote or subsidiary way muscular.

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ON THE NERVOUS SYSTEM OF COMATULA, WITH OBSERVATIONS ON THE MUTUAL AFFINITIES OF THE RECENT GROUPS OF ECHINODERMS. By A. MILNES MARSHALL, Professor of Zoology in Owens College, Manchester, England.

[ABSTRACT.]

OBSERVATIONS made this year at the Naples Zoölogical Station on living Comatulæ show that the main nervous system — both motor and sensory — of Comatula consists of the central capsule and axial cords embedded in the calcareous skeleton and that the ambulacral or subepithelial nervous system is of very subordinate importance.

In Asterids the nervous system is really in the form of a continuous sheath investing the whole body and continuous with the epidermis. From this primitive condition the nervous systems of other Echinoderms can be derived and important conclusions deduced concerning the relations of Crinoids to other Echinoderms.

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OBSERVATIONS UPON THE AMPHIBIAN BRAIN, CONTAINING RESULTS OF MICROSCOPIC STUDY UPON THE FROG, MENOBRANCHUS, MENOPOMA AND AMPHIUMA. By Prof. HENRY F. OSBORN, College of New Jersey, Princeton, N. J.

THESE observations have been carried on by the study of microscopic sections. These sections were cut in three planes, longitudinal vertical, longitudinal horizontal and transverse. The peculiarity of my method lies in the preservation of absolutely continuous series, in each plane, thus affording unusually reliable material for study. The brains are stained as a whole in carmine and imbedded for cutting in an egg mass, which is hardened in the vapor of alcohol.

The brains, thus studied, are those of *Rana*, *Menobranchus*, *Menopoma and Amphiuma*.

The paper is illustrated by a series of colored diagrams, and presents especially the following results:

(1) A description of the principal nerve fibre courses of the amphibian brain, from the medulla oblongata forwards to the

hemispheres, showing the course taken by the transverse commissures; pointing out a commissure in the roof of the third ventricle, hitherto overlooked, thus demonstrating that each brain segment has its own dorsal commissure. Under this head, is treated the cerebellum of the Urodela, showing how it differs from that of the Anoura, and possesses elements corresponding to the inferior and superior cerebellar peduncles of the mammalian brain.

(2) It is a matter of considerable doubt whether the pia-mater envelopes the pituitary body. At least the pia blood vessels are all sent in upon the anterior or brain face of the *pituitary* body.

(3) I endeavor to show that by all authorities, except Mihalkovics and Goette, the pineal gland has been erroneously described; that the plexus choroideus medius has been mistaken for the pineal gland. That the real *pineal* elements consist of certain very inconspicuous foldings of the epithelium of the roof of the 3rd ventricle, which have been generally overlooked. That these foldings represent what remains of the stalk of the pineal gland, and that this interpretation is sustained by the relations of these foldings to the posterior commissure and the newly described superior commissure.

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DO THE CEREBELLUM AND THE OBLONGATA REPRESENT TWO ENCEPHALIC SEGMENTS OR ONLY ONE? By Prof. BURT G. WILDER, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

SINCE the publication of Von Baer's "Entwickelungsgeschichte" in 1837, the segmental constitution of the brain has been more or less distinctly admitted by most writers who have treated the organ in the light of embryology and comparative anatomy.

Under various technical and vernacular designations, the following have recognized two segments between the myel[1] and the

[1] In the paper as presented the common forms *myelon* and *encephalon* were used. In correcting the proof I have substituted for them the English paronyms, in accordance with considerations presented in New York Medical Journal, March 28, 1885, and in the presidential address, "Paronymy versus Heteronymy," before the American Neurological Association, June 18, 1885.

mesencephal (optic lobes, etc.): Harrison Allen, Gegenbaur, Huxley, Kölliker, Lankester, Meynert, Mihalkovics, the editors of Quain's Anatomy (eighth and ninth editions), Reichert, Schwalbe, Wiedersheim and the present writer.

Omitting lesser parts, the cephalad of these two segments is held to include the cerebellum, together with the portion of the "brain stem," immediately connected therewith, and the latter. the part commonly called "medulla oblongata." By Von Baer and most other German writers the former is termed *hinterhirn*, and the latter *nachhirn*. I have adopted the Latin terms employed in Quain's anatomy, viz., *epencephal* and *metencephal*, abbreviated to *epen.* and *meten.* So far as I know, the only original investigators of the subject who have admitted but a single segment caudad of the mesen., are Balfour, Milnes Marshall, Owen and Spitzka, and the last named alone has discussed the question at any length.

That the entire region caudad of the mesen. should be regarded as a single segment, of which the cerebellum is "merely a dorsal hypertrophy" has been urged by Spitzka in 1878 ("Jour. of Nerv. and Mental Disease") in 1881, ("Science," April 9), and in a recent communication to "The New York Medical Record," July 26, 1884.

Before discussing the main question, I desire to correct a misapprehension into which Spitzka seems to have fallen respecting my own opinions. He implies, first, that I am committed to the view commonly entertained, and, second, that I regard the *pons* as determining the cephalocaudal extent of the epencephal.

On the contrary, as stated in "The Medical Record," Aug. 9, 1884, I have repeatedly expressed my sense of the difficulty of determining the precise number and limits of the encephalic segments, and admitted the force of Spitzka's own view. As to the pons, when present it strengthens the floor of the segment, and serves as a landmark of that region; but it by no means follows, and has never been implied by me, that either of its margins, especially in man, indicates the limits of the epencephalic segment, although in the cat and other mammalia with moderately developed cerebellums, one or both of its margins may closely correspond therewith.

In his able presentation of objections to the bisegmental con-

stitution of the region in question, Spitzka overlooks what appear to me to be weighty arguments in favor of the prevalent view, viz.:

(1) The existence, in the embryo, of a constriction of the "primary hind-brain" by which the "secondary hind-brain" is distinguishable from the "after-brain."

(2) The demarcation, at least in man, of the cephalad (epencephalic) portion of the "fourth ventricle," from the caudad (metencephalic) portion, by the transverse fasciculi called *striæ acusticæ*.

(3) The presence, in several Teleosts and Elasmobranchiates, of dorso-lateral, metencephalic masses, united by a thinner (commissural?) portion, and connected with the cerebellum only through a thin or membranous lamina comparable with the *valvula* between the cerebellum and the optic lobes. In the Torpedo (as seen in the preparation and photograph exhibited) each of these metencephalic masses exceeds in size the dorsal portions of all of the other segments together.

(4) In addition to these direct arguments, is the indirect one that most of the objections to the recognition of a cerebellar segment apply with equal force to the universally accepted mesen., and with even greater force to the oblongata (and thus to the brain as a whole) in relation to the myel. In other words, the meten. is more sharply defined from the epen. than it—and thus the entire brain—is from the myel.

(5) Finally, so far from the metepencephalic region embracing but a single segment, even if we hesitate to adopt Clevenger's idea that the cerebellum represents a series of coalesced intervertebral ganglia, we cannot ignore the suggestion of Balfour, based upon the observations of Gegenbaur, Marshall and himself, that several segments, each coördinate with the mesen., are represented in the region between it and the myel.

In view of all these considerations, it seems to me, first, that further investigations in embryology and comparative anatomy are needed to place upon a satisfactory basis any segmental formula of the brain; and, second, that the objections advanced by Spitzka should not prevent our entertaining and employing, as a convenient "working hypothesis" the interpretation made by Von Baer, and accepted by the majority of later authorities upon the subject.

## THE EXISTENCE AND DORSAL CIRCUMSCRIPTION OF THE PORTA (FORAMEN OF MONRO) IN THE ADULT HUMAN BRAIN.

By Prof. BURT G. WILDER, Cornell University, Ithaca, N. Y.

[ABSTRACT].

IN a paper, "On the foramina of Monro in man and the domestic cat," presented to the Association at the Boston meeting in 1880, it was stated (1) that no recent writer had denied the existence of a communication between each procœle (lateral ventricle) and the aula (cephalad part of the "third ventricle"); (2) that I had not yet had the opportunity of examining the parts upon a properly prepared human brain, but the imperfect materials at my disposal indicated that the relations are essentially the same as in the cat.

Since then, however (1) I find that, at the "Société de Biologie," May 14 and June 21, 1879, Prof. Mathias Duval declared that "when one finds a communication between the middle and lateral ventricles in an adult human brain, it results from an artificial perforation;" (2) I have been able to determine the existence and dorsal boundary of the porta in all the human brains examined for the purpose, including several adult as well as fetal and young. Some of these, like the specimen exhibited, were prepared by the process of continuous, cœlian alinjection (alcoholic injection) described by me at the last meeting of "The Society of Naturalists of the Eastern United States," and in "The New York Medical Journal," March 1, 1884. The photographs (taken by Prof. S. H. Gage) here shown are believed to be the first ever made of "the foramen of Monro;" in the enlarged one the orifice is seen to be bounded caudad by the thalamus, cephalad by the fornicolumn, ventrad by the continuity of the two, and dorsad by the endyma reflected from the parts named upon the intruded portiplexus.

As has been repeatedly stated by me, this demonstration of the dorsal limit of the porta is equally a demonstration of the ventral limit of the rima ("great transverse fissure") with which the porta is usually, but erroneously, made continuous in both figures and descriptions.[1]

[1] Since this paper was presented, I have been enabled to see the same points to even better advantage upon an alinjected hydrencephal (hydrocephalous brain), shown at the meeting of the Am. Neurological Assoc., June 18, 1885.

THE RELATIVE POSITION OF THE CEREBRUM AND THE CEREBELLUM IN ANTHROPOID APES. By Prof. BURT G. WILDER, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

So far as I am aware, the discussion as to whether or not the cerebellum of the anthropoid apes is completely covered by the cerebrum has not been based upon the examination of a brain hardened within the cranium, or upon photographs taken before its removal. Through the courtesy of Prof. H. C. Chapman, M. D., one of the directors of the Philadelphia Zoölogical Gardens, and of Mr. Arthur E. Brown, superintendent of the same, the opportunity was afforded me, last October, of so treating the brain of a young female chimpanzee, supposed by Mr. Brown to be about four years old; the day after its death it weighed 6.7 kilograms.

For ten days, at a temperature ranging from four to fifteen degrees centigrade, the entire animal was subjected to the process of *continuous arterial alinjection* (alcoholic injection) described by me at the last meeting of the Society of Naturalists of the Eastern United States, and in "The New York Medical Journal," for Feb. 23, 1884, and elsewhere. On the second day, less than half of the calvarium was removed, and photographs taken of the dura-covered brain; later, after the removal of the dura, and then of the other part of the calvarium, and of the brain itself, photographs were taken from several points of view.

As shown by these photographs and by the left half of the brain, here exhibited, when the specimen is held so that the ventral outline of the orbital lobe is horizontal, the most prominent portion of the cerebellum is overlapped at least 1 mm. by the extremity of the occipital lobes of the cerebrum.

Admitting the possibility, suggested by Chapman, of individual; age and specific variations, it is probable that, in some cases, as suggested by Spitzka, the conclusion that the anthropoid cerebellum is not overlapped by the cerebrum has been due to the distortion of the brain during or after its removal.

In addition to these considerations, it is evident that the relative positions of the parts will depend upon the way the brain is held. Until evidence is given to the contrary, I assume that the brain should be held as if the animal were looking horizontally.

## SOME QUESTIONS IN ANATOMICAL NOMENCLATURE. By Prof. BURT G. WILDER, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

SINCE 1870, in various publications, I have urged upon anatomists certain modifications of the existing terminology of description and designation. Even by those who have not accepted my specific recommendations, it is quite generally admitted that some change is needed. I now ask for the appointment of a "Committee on Anatomical Nomenclature," by Section F, to report at the next meeting upon the general subject, especially with respect to the brain; this committee to invite the coöperation of anatomists of other nationalities, and to confer respecting encephalic nomenclature with the Committee on that subject appointed at its last meeting by the American Neurological Association.

The following are examples of the more general and special questions to be considered by such committee:

1. Is it desirable to employ the words *toponymy* and *organonymy*, respectively, for the subjects of descriptive and designatory terms?

2. Is it practicable, at present, to harmonize the toponymic terminology of vertebrates with that of any invertebrates?

3. Should we not agree upon a certain normal position of the vertebrate body, including the limbs, and endeavor to use toponymic terms applicable equally to all?

4. Should not *postaxial*, *epaxial*, etc., as applied to the limbs, be replaced by terms referring to the regions of the entire body.

5. Shall the median plane or line be designated by those or other phrases, by Barclay's *mesium*, or my *meson* (*τό μέσον*, the middle), with the derivatives *mesal*, *mesad* and *meso?*

6. In designating relative position along the longitudinal axis of the body, since *oral*, *cephalic* and *caudal* are commonly employed in an absolute sense, shall we follow the analogy of *northward* and use the adverbial adjectives *orad*, *cephalad* and *caudad;* or new terms like *prorsal* and *retral;* or the familiar words *anterior* and *posterior*, with the understanding that they are never to be used in the anthropotomic sense of *ventral* and *dorsal?*

7. Should not organonymic terms (terms of designation) be,

as far as practicable, *brief; capable of inflection; classic in derivation and form*;[1] *already used in a kindred sense?*

8. Since the length of a term may depend upon not only the number of syllables and letters, but also upon the number of separate words, and since, properly, only single words are capable of inflection, is there not a twofold reason why the names of parts, with certain self-evident exceptions (nerves, etc.) should be *mononymic?*

9. Is there much real analogy between the nomenclature of anatomy and that of zoology and botany?

10. How far should priority be regarded in the selection of existing names?

11. Can priority be claimed for terms which are vernacular or descriptive?

12. In considering all questions of terminological reform, should we not regard less our present and personal convenience, than the interests of the vastly more numerous anatomical workers of the future?

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PRELIMINARY NOTE ON THE LYMPHATICS OF THE COMMON BULLHEAD, AMIURUS CATUS (L.), GILL. By F. L. KILBORNE, B. V. S., Cornell University, Ithaca, N. Y.

THE lymphatic system of fishes seems to have received comparatively little attention from working anatomists. The literature upon the subject, especially in English, is very meagre, and even in French and German there is little more. Hewson, as early as 1768–9, first described the lymphatics of amphibious animals and fishes. Besides his paper I have been able to find in English but a single short note by T. R. Jones upon the lymph heart of

[1] In later papers ("Encephalic Nomenclature," N. Y. Med. Jour., April 21, 28, 1885, and "Paronymy versus Heteronymy as Neuronymic Principles", the presidential address before the American Neurological Association, 1885, "Jour. of Nervous and Mental Disease," July, 1885), I have suggested that, in English works, so far as possible, the *names be given an English aspect by paronymisation.* For example, *commissura* becomes *commissure; pedunculus, peduncle; mesocœlia, mesocœle; myelum, myel; and encephalum, encephal.* With many names no change is needed, as with *porta, aula, fornix, callosum,* etc. *Heteronyms* or vernacular translations are regarded as objectionable. The same principle is applicable to other languages.

the common eel. Günther, in his "Introduction to the study of fishes" does not mention the lymphatics although every other system is quite fully treated. T. R. Jones in his "General outline of the organization of the animal kingdom, and manual of comparative anatomy," speaks of the lymphatics of fishes as a "system of vessels abundantly distributed through the body," and which "ramify like a rich network over the wall of the intestine." Owen and Huxley treat them very briefly in general but give little in detail. In no author do I find this system described as it exists in the common bull-head of the eastern and middle states.

As the result of investigations carried on in the anatomical laboratory of Cornell University the lymphatic system of the bull-head is found to consist of sinuses, plexuses, trunks and capillaries, the most important of which are: (1) a large visceral sinus with its plexuses, (2) two peritoneal sinuses, (3) a pericardial plexus, (4) a large trunk at the base of each fin and (5) two subvertebral trunks in the abdomen.

One of the simplest methods by which these lymphatics may be demonstrated is by injecting starch or gelatin into the large lymphatic trunk which runs through the base of the anal fin; the injection should be made in both directions in order to fill the entire system. Care should be taken, however, to first inject the veins, otherwise it would be impossible to distinguish lymphatics from veins, so closely are they connected.

From the cephalic end of the anal fin this lymphatic trunk passes cephalo-dorsad to enter the abdominal cavity at its extreme caudal end. Here it immediately divides into a right and left branch to form a large lymphatic sinus on each side attached to the parietal peritoneum just ventrad of the kidneys and extending cephalad as far as the kidneys. These I have designated as the peritoneal sinuses. From the end of each of these sinuses a trunk extends cephalad along the abdominal wall until opposite the middle of the stomach where each passes mesad to enter the large visceral sinus. This irregular branching sinus covers nearly the whole of the dorsal wall of the stomach and extends some distance caudad along the coil of the small intestine before it divides into two or three trunks which pass along the mesal borders of the reproductive organs and large intestine to join the peritoneal sinuses at their junction. The visceral sinus is the most extensive sinus of the lymphatic system, and by the aid of numerous plexuses and small trunks receives all the

lymphatics of the stomach and intestines. It receives branches on each side from the pectoral fins and also from the pericardial plexus. The two subvertebral trunks in the abdomen receive the lymphatics of the cranium and the dorsal fin, and communicate by several branches with the peritoneal sinuses. A lymphatic trunk from each of the ventral fins joins the large trunk from the anal fin about midway between that fin and the abdominal cavity. In one instance they were also observed to communicate with the peritoneal sinuses by small branches.

At the caudal end of the anal fin the lymphatic trunk divides into two branches which pass dorsad and empty into the cardinal veins. The lymphatic trunk in the base of the caudal fin likewise sends one or more branches to the cardinal veins. These are the only direct communications between lymphatics and veins which I have been able thus far to satisfactorily demonstrate; but judging from the condition described in other fishes there are probably other communications. In no case were lymphatic sinuses found in the tail as described by Owen, Huxley and others for fishes in general.

The lymphatics as observed in the fins consist of the large trunk at their base, from which a branch extends along each border of the fin-rays toward their tips; these branches give off numerous smaller branches to the space between the fin-rays and continually subdividing form an anastomosing, capillary network between the lymphatic branches of adjacent fin-rays. If the tips of the fins are slightly broken, or the pressure in injecting is too great, the branches along the fin-rays will become ruptured at the free border of the fin, allowing the injecting mass to escape in a fine stream.

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OBSERVATIONS ON THE INFLUENCE OF OXYGENATED AND NON-OXYGENATED BLOOD AS WELL AS OF BLOOD IN VARIOUS DEGREES OF DILUTION ON THE ISOLATED HEART OF THE FROG AND SLIDER TERRAPIN. By Dr. H. G. BEYER, U. S. National Museum, Washington, D. C.

[ABSTRACT.]

THIS paper is to prove that it is not concentrated mammalian blood which produces the greatest amount of work done by either

the heart of the frog or that of the terrapin, but a certain degree of dilution is necessary for that purpose.

It furthermore shows that there is no exception to the constant stimulating influence of oxygenated blood upon the isolated heart, and none to the constant depressing effect of non-oxygenated or carbonic-acid blood.

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EXPERIMENTAL RESEARCH RELATING TO THE ETIOLOGY OF TUBERCULOSIS. By GEORGE M. STERNBERG, M. D., Major and Surgeon, U. S. A., Baltimore, Md.

[ABSTRACT.]

THE writer has repeated Koch's inoculation experiments and is able to confirm him as to the infectious nature of tuberculosis, and also as to the presence of the bacillus discovered by him in tubercle nodules in the lungs, and in tuberculous glands, of inoculated rabbits and guinea pigs (inoculated with sputum of phthisical patients).

The experiments of Formad of Philadelphia, in which he claims to produce tuberculosis in rabbits by the introduction into the cavity of the abdomen of finely powdered inorganic material, have also been repeated, with an entirely negative result so far as the production of tuberculosis is concerned.

The conclusion is therefore reached that the bacillus of Koch is an essential factor in the etiology of tuberculosis.

A full report of these experiments will be published hereafter in some medical journal.

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ON THE MORPHOLOGY AND EVOLUTION OF THE TAILS OF OSSEOUS FISHES. By JOHN A. RYDER, Smithsonian Institution, Washington, D. C.

[ABSTRACT.]

THE caudal fin of fishes is developed in the same way as the other median or unpaired fins from a median fin-fold, and the object of the present communication is to show its relation to the other median fins, also to show that after the protocercal stage of

the larva is passed, a lower caudal lobe grows out which is probably the homologue of a second anal, for which reasons will be assigned. The hypotheses which grow out of a consideration of the facts of the development of the tails of fishes are the following:—

1. Whenever heterocercality manifests itself there is a more or less extensive degeneration of the caudal end of the chordal axis, which began to become manifest far back in the phylum in such forms as the *Holocephali*, *Dipnoi* and *Cronopterygians*.

2. With the outgrowth of the lower lobe (second anal), the energy of growth tended to push the tip of the chorda upward, the lobe itself arising probably in consequence of the localization of the energy of growth and the deposit of organic material at this point according to the demands of use and effort.

3. Local use and effort acting as constant stimuli of local growth carried the heterocercal condition and its accompanying modifications of degeneration and reduction still farther, as is shown by a study of the homologous elements in the tails of fishes; while use and effort would also continue to augment heterocercality until the inferior and superior lobes were about of the same length and area, when the morphological characters of the caudal fin would become approximately stable for any one species, as may be shown by means of a simple mechanical illustration in which the interaction and composition of the forces which are brought into action while the tail is being used are demonstrated.

4. The mechanical demonstration alluded to above, taken together with the fact that the primitive or ancestral form of the tail, which is typified by a temporary condition in fish larvæ, when the myocommata are rudimentary but still symmetrical, amounts almost to a demonstration of the principles first laid down by Lamarck, then elaborated by Spencer, and more recently applied to special cases by Professor Cope and myself.

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ON SOME POINTS IN THE DEVELOPMENT OF PELAGIC TELEOSTEAN EGGS. By GEORGE BROOK, jr., F. L. S., Huddersfield, Eng.

[ABSTRACT.]

PELAGIC teleostean eggs differ in several important points of development from non-pelagic eggs.

(a) In the trout which may be taken as a type of the non-pelagic

group the hypoblast originates as an involution of the lower layer upon itself according to Henneguy and the space between the two layers is quite distinct. The absorption of free cells from the yolk is quite a minor feature in this case. In pelagic eggs I am convinced the process is different. Sections of the egg of *Trachinus vipera* about this stage show that into the pasablast of Klein, the intermediary layer of American authors, a large number of free cells and nuclei are absorbed from the yolk which contribute to a very great extent to build up the hypoblast. In this case there is no true invagination, nor are the lower layer cells curved under on themselves as is described by Henneguy for the trout. In *Motella mustela*, which I have also studied, the hypoblast appears to originate much in the same way as in *Trachinus;* but the resulting cells, instead of being quite similar to the original ones as is usual in *Teleosteans*, are very much larger and hexagonal so that there can be no doubt they are not derived directly from the lower layer cells. Kingsley and Conn, in their paper on the development of the cunner, state that the hypoblast originates by the invagination of the epidermic layer of the epiblast. This may appear the case in "optical" section of the living egg, but I feel sure that actual sections of the blastoderm will show that the epidermic layer is continued some distance beyond the point of invagination and takes no part whatever in the process.

(*b*) In the species of pelagic eggs which I have examined, I have always found the segmentation cavity to persist as is described by Ryder for the Spanish mackerel (Bull. U. S. Fish Comm. Vol. I) and by myself for the Lesser Weever fish (Linn. Soc. Jour. Vol. XVIII). Mr. Kingsley also seems now to have changed his opinion on this point and to agree with Ryder's main points.

(*c*) The late stage at which any circulation is to be observed in the floating eggs already described is in striking contrast with the early circulation both in the embryo and the yolk sac which obtains in non-pelagic eggs. So far as I am aware no circulation has been observed in pelagic eggs up to time of hatching so that the circulatory system is quite late in developing.

STRUCTURE AND DEVELOPMENT OF THE SUSPENSORY LIGAMENT IN THE HORSE, OX AND SHEEP. By D. J. CUNNINGHAM, Professor of Anatomy, Trinity College, Dublin, Ireland.

[ABSTRACT.]

THIS paper contained a short account of how muscles of the foot in the animals mentioned are converted into ligamentous structures, and was illustrated by microscopic specimens.

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ON THE PRESENCE OF EYES, AND OTHER SENSE ORGANS ON THE SHELLS OF THE CHITONIDÆ. By HENRY N. MOSELEY, Professor of Anatomy, University of Oxford, England.

[ABSTRACT.]

THE tegmentary part of the shell of the Chitonidæ is traversed by a series of ramifying canals, which in most forms terminate at the exposed surfaces of the shells in numerous fine pores of two dimensions, large and small, which may be conveniently termed megalopores and micropores. These pores are arranged on the shell surfaces in definite patterns. The canal ramifications are occupied in the recent state of the animals by corresponding ramifications of soft tissue and nerves, prolongations of the mantle tissues.

The ramifications of soft tissue terminate in the megalopores and micropores in cylindrical or sausage-shaped tactile organs of two sizes which may be termed megalæsthetes and micræsthetes. These organs differ in form in the different genera. The megalæsthetes lie in the megalopores and the micræsthetes in the micropores, and both can apparently be protruded from their pores to exercise their tactile function. The micræsthetes are supplied by nerves which are given off from the sides of the megalæsthetes. In certain genera of Chitonidæ, eyes are present in the tegmenta of the shells variously disposed at their surfaces among the pores. These eyes receive their nerves from the same network as that which supplies the organs of touch, the optic nerves being simply

offsets of this network in no way differing from those supplying the micræsthetes. The eyes consist each of a calcareous convex cornea continuous with the surface layer of the shell, a biconvex lens of soft tissue and a retina, which is constructed on the same type as that of Helix, having a layer of rods on its surface which is exposed to the lens and the light. The retina thus does not correspond in structure as might have been expected with that of the dorsal eyes of Oncidium or the eyes of Pecten. The chamber of each eye is pear-shaped and enclosed by a darkly pigmented choroid membrane which is inflected at the mouth of the chamber to form a sort of iris round the lens. The optic nerve gives off all round, before expanding into the retina, a series of fine offsets which perforate the iris region of the choroid and terminate at the shell surface in a zone of micræsthetes round the eye which are exactly similar in structure to those supplied with nerve offsets from the micræsthetes as already described. From this circumstance and the general facts of structure, there seems to be no doubt that the eyes are homologous with the micræsthetes and are special modifications of them.

In the genera Chiton, Molpalia, Maugina, Lorica, Ischnochiton and Chitonellus there appear to be no eyes, only the tactile organs being present.

The eyes are largest in Schizochiton in which genus they were first discovered. They are always entirely confined to the tegmental region of the shells. They are best seen in shells moistened with spirits and appear on them, under a powerful lens, as brilliant highly refracting convex objects. In Schizochiton the eyes are arranged in single linear rows of which there are two on each intermediate shell and six on the anterior and posterior shells, 360 eyes in all being present. The eyes measure about $\frac{1}{175}$th of an inch in diameter. In *Corephium aculeatum*, the eyes are very small and oval in outline of the cornea. They measure $\frac{1}{800}$th by $\frac{1}{600}$th of an inch. There appears from a rough estimate to be about 3,000 eyes on the anterior shell and 11,000 on the entire series of eight shells.

The eyes are constantly being formed at the margins of the tegmenta by the mantle as the shells grow. They can be seen in all stages of formation. In some Chitonidæ they become removed by wear and erosion on the older parts of the shell. In some gen-

era, as in Tonicia, they are sunk in depressions of the shell surface, and thus protected from wear survive all over the shells throughout life.

A full account of the above results fully illustrated will be published in the January number of the Quarterly Journal of Microscopical Science.

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ON THE FRILLED SHARK. By S. GARMAN, Assistant, Museum of Comparative Zoology, Cambridge, Mass.

[ABSTRACT.]

CHLAMYDOSELACHUS ANGUINEUS Garman, 1884, Jan. 17, Bulletin Essex Institute, Vol. XVI.

A preliminary description based on the external characters of this shark has already been published in the Bulletin of the Essex Institute, Vol. XVI, p. 47. The present paper is an abstract of an anatomical and comparative study of details, which has been made possible by the liberality of Professor Alex. Agassiz. The results of the study confirm the conclusions advanced in my first publication on the subject concerning the relations of this genus to the Cladodonts and to the living Selachia. As determined from the teeth, which represent all that is at present known of the extinct Cladodonti, the affinities of *Chlamydoselachus* reach back to that group as found in the Sub-Carboniferous and Middle Devonian. Until we know more of their general structure, the genus under consideration must stand as one of the Cladodonts, at this date their only known recent representative. Under dissection the skeletal structure shows quite as emphatically as the dentition that the claim of Professor Cope that this shark belongs to his genus Didymodus is not based on knowledge of the animal.

*Didymodus* cannot rightly be placed in the sub-order containing this shark. *Chlamydoselachus* is a shark, though differing, in various respects, quite enough to be very distinct from the other recent genera. It approaches them most nearly in *Heptabranchias* of the *Notidanidae*. Prominent resemblances occur in the number of gill arches, the shape of the brain, the origins of the nerves, and other features. The great differences in shapes of body, head and tail, in dentition and squamation have already been indicated in

the description. If these genera were now extinct, and had left us but the teeth, or teeth and scales, close affinities between them would have been among the last to be suspected. Additional and important differences between them appear in the skull, the vertebræ, the pelvis, the cartilages of dorsal, ventral and tail, in the heart, vascular system and elsewhere. The skull compares better with that of the embryo *Heptabranchias* than with that of the adult. The notochord is persistent; it is not divided into segments, but merely constricted, about half its width, by the anterior vertebræ; in the posterior and greater portion of its length, its diameter is uniform, without constrictions. The pelvis is much elongated, and numerous radials articulate directly with it. A much longer extent is occupied by the cartilages of the dorsal than is usual, as compared with the extent of the fin. It is as if ancestors had possessed a dorsal of greater length—one that agreed better in proportions with the anal, but which had become reduced in length more rapidly in the fin than in the basal cartilages. Instead of tapering gradually to a point, as in sharks generally, the vertebral column stops with abruptness at a width of about five-eighths of an inch, and the canal is closed by a small lump of soft cartilage. Of the heart the bulbus is long and contains seven rows of valves, the proximal of which is occupied by a single valve. *Heptabranchias* has been considered to have a normal number of but three rows, A specimen of *H. maculatus* before me has a short bulbus with three rows,but in the middle of its length there are traces of two other rows which have become obsolete. In a very young *H. pectorosus*, the bulbus is short also, and has five rows of valves, which suggests a possible loss, or undeveloped condition, of two rows later in life. The only specimen of *Chlamydoselachus* that has come to our notice belongs to the Museum of Comparative Zoology at Cambridge, Mass. The complete paper illustrated with numerous figures of the anatomy will be published by the Museum.

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ON THE HITHERTO UNKNOWN MODE OF OVIPOSITION IN THE CARABIDÆ. By Prof. C. V. RILEY, U. S. Entomologist, Washington, D. C.

[ABSTRACT.]

THE Carabidæ constitute one of the leading, largest and best known families of *Coleoptera*. Its members are chiefly preda-

ceous, and are quite commonly met with both in the larva and imago states, in all sorts of localities, either hiding under logs or stones, or scampering over the ground—whence the popular name of ground-beetles. Considering their numbers and frequency it is remarkable that nothing at all definite is on record, as to their mode of oviposition. The paper records the actual habit in one species (*Chlœnius impunctifrons*) traced from the egg to the imago by breeding, and strong proof of the similar habit in another species of the genus, viz., *Chlœnius œstivus*, in *Scarites subterraneus*, and in the genera *Dicœlus* and *Galerita*. The remarkable and unexpected fact, in insects so essentially terrestrial, is that the eggs are laid singly on the leaves of trees and shrubs, and encased in a shell of mud or clay. The eggs and the larvæ are described, and the manner of forming the case; the object of the habit and the probabilities of its being normal in the family, discussed. Instances of equally remarkable oviposition away from the food or habitat of the larva are mentioned in the Lepidoptera, Diptera and Neuroptera.

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THE HABITS OF SOME ARVICOLINÆ. By EDGAR R. QUICK and A. W. BUTLER, Brookville, Ind.

FOUR species of Arvicolinæ have been found in southeastern Indiana. *Synaptomys cooperi* Bd., *Arvicola pinetorum* Le C., *Arvicola riparius* Le C., and *Arvicola austerus* Ord.

The credit of the discovery of Cooper's field mouse, in Indiana, belongs to Rufus Haymond, who in 1866 sent a specimen of this mouse from Brookville, to the Smithsonian Institution. This mouse is numbered 9963 in the Smithsonian collection. No other specimen was taken in Indiana for several years. In 1879 one of the writers took the second specimen, about three miles south of Brookville, and four miles from where the first one was taken. Specimen after specimen followed this one, all being taken from the same locality.

From the most reliable information obtainable, we conclude that less than fifty specimens of this little mammal have been taken, of

which number, more than half have been taken by the writers from this locality.

This mouse is found on hillsides, in high, dry, blue-grass pastures, where flat stones abound. It especially prefers what are known as "woods pastures," containing little or no undergrowth.

Cooper's field mouse has been found breeding from February to December. It has never been known by the author to bring forth more than four young at a time. In all suckling females which have been examined by us, but four mammæ were apparent, one pair pectoral and the other inguinal.

In young specimens, the hair appears finer, shorter, and more glossy, than in more aged examples. As a rule, the specimens just reaching maturity are darkest, but one old female shows a very dark reddish-brown back and is dark ash below.

The nest of this species is always under cover, generally beneath a log or stump, and is composed of fine grass not very securely held together.

Cooper's mice live in winter chiefly upon the stems of blue-grass, and the more tender portions of white clover. The roots of the "wild artichoke," *Helianthus doronicoides* Lam., have also been found in quantities in their storehouses.

These mice vary much in numbers, in different years. In 1879 they were very common on a hill south of Brookville. This year no examples of *S. cooperi* have been taken on this hill, but a single specimen was found not far distant.

Cooper's mouse is the most active representative of its family in this locality. It is most frequently found by turning over logs and stones, beneath which it remains concealed.

The second representative of this family, *Arvicola pinetorum* Le C., pine mouse, has been considered rare in this locality, but in a two hours' hunt in February last, eleven specimens were taken. This species strongly resembles a mole in form, especially in the size of its fore feet and of the forward part of its body. Its habits are also somewhat similar. The runways of the pine mouse are nearly always under ground. They frequent the higher part of steep, partially wooded hills, in winter occupying the warmer exposures. When the covering is suddenly removed from their winter quarters, they appear dazzled by the light, and for an instant, can be easily caught. Of this opportunity, one must take

advantage, or they suddenly disappear among their intricate underground passages where they are quite safe.

The nest of the pine mouse is a round ball of blue-grass blades, from four to six inches in diameter. The interior is composed of fine grass. The nest is generally placed beneath a pile of leaves or an old stump. These nests are often occupied by the mice as winter quarters.

The pine mouse, in winter, lives upon the tender roots of young hickories, *Carya alba* Nutt., the young sprouts of white clover, *Trifolium repens* L., the fruit of the red haw, *Cratægus coccinea* L., and the tuberous roots of the "wild violet," *Viola cucullata* Ait. These products, except the first, are found stored in large quantities. As much as a gallon of the tubers of the wild violet have been found, buried by these mice, eighteen inches below the surface of the ground.

The common meadow mouse, *Arvicola riparius* Le C., is the most common mammal in southeastern Indiana. Some years they are very numerous, the ground being literally honeycombed by their passages. After the early snows have fallen, corn shocks will be found thickly colonized by these little pests, who find there, not only comfortable quarters, but a well filled granary from which to draw their winter's food. Should the snow remain on the ground for any great length of time, the runways of these mice will show that their explorations have been extended almost everywhere.

Their food in winter is the corn found in the thriftless farmer's shocks, the seeds of a number of common plants, and the young blades of the blue-grass.

Their large round nests remind one of miniature musk-rat houses. They are constructed of grass strongly interwoven. The single opening to their home is below, connecting with their runways. These nests are found in almost every conceivable place: in thickets, swampy places, in fence corners, and many in open clover-fields where the mice prey upon the nests of the humble bees.

The meadow mice breed from February to December. *Arvicola austerus* Ord., called by some authorities "prairie meadow mouse" is the rarest of the family in this locality. We think Dr. Langdon very properly calls this species, the "wood mouse" on account of its attachment to the more open woodland, or the grassy

fields and newly cleared land adjoining such. All the specimens seen here have been caught by a cat, hence we are unacquainted with its habits.

Those of the above mentioned species with which we are best acquainted occur at times in great numbers, while in other years they are scarce. During the years 1878–79, *Arvicola riparius* was very common, but in 1880 most of them disappeared, and for a long time they were very scarce. They have slowly increased in numbers since that time and are now as numerous perhaps as ever.

The principal enemies of these mice are the smaller hawks (*Tinnuculus sparverius* Vieill.; *Accipiter fuscus* Bp.; and *Accipiter cooperi* Bd.); and owls (*Scops asio* Bp.; and *Asio accipitrinus* Bd.). Cats and dogs catch them as opportunity affords. Many are also killed by shrews.

All of these mice are gregarious. Their habits differ to a considerable extent. Each species lives on some particular food found near its home. Except in the case of the pine mouse and Cooper's mouse, the local ranges of no two species overlap; each frequents a particular locality, from which it plays its part in the economy of nature.

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FEATHERS OF THE DODO. By H. N. MOSELEY, Professor of Anatomy, University of Oxford, England.

[ABSTRACT.]

PROFESSOR MOSELEY exhibited a drawing showing the arrangement of the follicles of the feathers in the unique specimen of the skin of the head of the dodo (*Didus ineptus*) belonging to the University of Oxford. Unlike what occurs in all other birds, in the dodo all the feathers are disposed in groups of three which are nearly equal in size. This arrangement of the feathers is shown in one of the ancient oil-paintings of the dodo, by Savery, belonging also to the Oxford collection. It seems probable that the two lateral feathers, in each group of three, are homologous with the pair of minute rudimentary feathers, termed filoplumes, which in the pigeons lie on either side of the follicle of each main-feather. It seems probable that in the dodo, and in the ancestral

pigeons, the feathers were disposed in groups of three of nearly similar dimensions, and that in course of development the lateral feathers of each group have been reduced to the rudimentary filoplume condition by the preponderance of the central main feather.

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THE HOOD OF THE HOODED SEAL (CYSTOPHORA CRISTATA). By C. HART MERRIAM, M. D., Locust Grove, N. Y.

[ABSTRACT.]

WRITERS upon Pinnipeds agree in stating that the curious appendage variously known as the "hood", "cap", or "bladder" of the hooded seal is placed upon the top of the head, and is capable (in some wholly unexplained way) of being drawn over the eyes at will. As a matter of fact, it is an inflatable proboscis overhanging the mouth and extending posteriorly to a point a little behind the eyes. It is lined by a continuation of the nasal mucous membrane, and is divided longitudinally into two distinct chambers, by a continuation and expansion of the nasal septum. It is supported by three cartilages—one median and two lateral. It is only present in the males, and does not become noticeable till the fourth year. It is purely a sexual development and its function, if any, is unknown.

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HIBERNATION OF THE LOWER VERTEBRATES. By A. W. BUTLER, Brookville, Ind.

[ABSTRACT.]

I HAVE for several years, as opportunity offered, carefully noted my observations of the "Lower vertebrates," in southeastern Indiana. The question of hibernation of this portion of the animal kingdom has recently been brought to our attention, and in this connection I will present my observations upon this subject.

The common "box tortoise" of this region hibernates regularly. It frequents the drier woodland, partially overgrown with underbrush. It enters the ground the latter part of September or early

in October to a depth of not more than a foot, the average being from eight to ten inches. A few years ago, in March, I was burning over a tract of woodland, on which were a number of brush piles. When the fire burned out I passed where some of these brush piles had been. I noticed the ground appeared to be torn up as though a charge from a shot gun had been fired into it. Examination in several instances revealed the fact that the work had been done by tortoises. The heat had aroused them from their winter quarters, and they sought the surface and the cause of their sudden awakening.

The day being quite cool, I placed them in a beaten road which passed through the woods, and awaited further developments. The tortoises appeared to realize that they had entered upon their summer career too soon, and in a few moments they were all safely buried beneath the neighboring brush piles and leaves.

The box tortoise emerges from its winter quarters late in April or early in May.

All the river and pond turtles hibernate in this locality. The "soft shelled turtles" burrow deep into the mud, while their "hard shelled" relatives, not being so susceptible to climatic changes, do not winter at such a depth.

I have under my charge a water power canal, parts of which are thickly populated by turtles. In winter while making repairs, "hard shelled" turtles are often found at four to twelve inches beneath the earth, in the bed of the canal. When one is found we feel confident of finding two to four companions near by. The White Water Rivers are very clear in winter, enabling one to examine even their deeper portions to advantage. I have never been able to hear of an instance where a turtle has been seen, even in the deepest water: besides, the deeper holes are seined almost every winter, and I have been unable to learn of a turtle ever having been drawn out by a seine at that time of the year.

My fellow worker, Mr. E. R. Quick, mentions two instances of turtles leaving ponds which became dry in winter. On one of these occasions he noticed the tracks of a turtle in the snow which he thinks were made while the snow was melting.

I have found "hard shelled" turtles that had been left some distance from the river by the winter's floods. They appeared dead, but when brought to the fire became quite active. "Soft shelled" turtles when found under these circumstances never recover.

Our more tender fish hibernate, but many hardy species occupy the deeper pools of our rivers, where they are caught in large numbers by means of seines and other nets. The species most commonly caught in this manner are the "quill backs" (*Carpoides velifer* Rafinesque and *C. cutisanserinus* Cope), "white sucker" (*Catostomus teres* Le S.) and the "hog sucker" or "molly hog"(*C. nigricans* Le S.). The latter is the hardiest of our fishes. It is found in winter in shallow water six to twelve inches in depth. When the streams are frozen over, just enough to bear a man in safety, many "molly hogs" are killed by striking a heavy blow with an axe just above where they lie.

The common toad regularly hibernates in sandy soil, burrowing to the depth of eighteen inches. In clayey ground, the average depth attained is about eight inches. They frequent gardens and are often uncovered in the autumn by the farmers, when burying farm produce and apples. In early spring they are frequently thrown out by the spade during early gardening, and in a few moments hop off, apparently without impediment.

Frogs are at times found some distance from water, passing the winter burrowed in damp places. Early last spring, two leopard frogs(*Rana halecina* Kalm.)were found in a cellar window buried beneath the accumulations of the past year. The weather was quite cool, and the frogs appeared to be dead, but when taken into a warm room they soon revived and began croaking. The locality just mentioned is on a ridge about seventy-five feet above, and over three hundred yards in a horizontal direction from the river.

As a rule, newts and salamanders do not enter the ground, but spend the winter in springs and beneath leaves and logs in the damper woods. I have found them in winter, when the springs were not frozen, to be quite active. I have taken the common newt on several occasions in damp woods, under logs, when they appeared to be frozen, but when placed in the sun or held in the hand for a short time, they revived. Early in March the woodland ponds teem with salamanders of different species.

From my observations, of which the preceding notes are abstracts, I conclude: that in this part of the Ohio Valley tortoises, turtles, toads and frogs are regularly found hibernating; while on the other hand newts, salamanders and many species of fish do not as a rule enter a torpid state.

## TITLES OF OTHER PAPERS READ IN SECTION F.

ON THE IDENTIFICATION OF THE ANIMALS AND PLANTS OF INDIA WHICH ARE MENTIONED BY ANCIENT GREEK AUTHORS. By Prof. V. BALL, Director Science and Art Museum, Dublin, Ireland.

EXHIBITION OF SPIDERS. By J. H. EMERTON, New Haven, Conn.

STATEMENT OF PLAN FOR OBSERVING THE MIGRATIONS OF BIRDS IN ALL INHABITED PARTS OF THE EARTH. By Dr. C. HART MERRIAM, Locust Grove, N. Y. (Delegate from the Ornithologischer Verein in Wien.)

ON A SPECIAL FUNCTION OF THE EXTERNAL THIRD OF THE LENTICULAR NUCLEUS OF THE CORPUS STRIATUM. By CHARLES PORTER HART, Wyoming, Ohio.

EXPERIMENTAL RESEARCHES ON THE SO-CALLED THOUGHT TRANSFERENCE. By L. F. BARRETT, London, England.

ALLEGED SENSORY EFFECTS OF MAGNETISM. By L. F. BARRETT, London, England.

ON FINGER MUSCLES IN MEGAPTERA LONGIMANA, AND IN OTHER WHALES. By JOHN STRUTHERS, M. D., Professor of Anatomy, Aberdeen University, Scotland.

PRELIMINARY NOTES ON THE DELICACY OF THE SPECIAL SENSES. By E. H. S. BAILEY, Lawrence, Kansas, and Dr. E. L. NICHOLS, University of Kansas, Lawrence, Kansas.

ETHIDENE DICHLORIDE AS AN ANESTHETIC. By JOHN MCKENDRICK, Professor of Physiology, University of Glasgow, Scotland.

AFFINITIES OF DIONAEA. By JOS. F. JAMES, Cincinnati, Ohio.

A NEW PARASITIC COPEPOD FROM THE CLAM. (MYA ARENARIA). By Prof. R. RAMSEY WRIGHT, University College, Toronto, Canada.

DEVELOPMENT OF LIMULUS. By J. S. KINGSLEY, Malden, Mass.

# SECTION G.

# HISTOLOGY AND MICROSCOPY.

# ADDRESS

BY

## PROFESSOR T. G. WORMLEY,

VICE PRESIDENT, SECTION G.

## *THE APPLICATIONS OF THE MICROSCOPE.*[1]

THE subject was the applications of the microscope in chemical and micrometric observations. The microscope, he said, frequently enables us to determine in a moment questions which, without its aid, would require hours and days. Thus: If a piece of bright copper be placed in an acid solution containing arsenic and heated, the copper becomes coated with a dark deposit. This is common to several metals; but if the copper strip be then placed in a small tube and heated, the arsenic will be sublimed, and will condense in the cool part of the tube in minute octahedral crystals, which may be recognized with a microscope. If the copper be coated with mercury, opaque microscopic globules of that metal will be found in the sublimate. Quantities of metal, alkaloids, etc., much smaller than can be detected by chemical tests, can be discovered in this way. Of the two metals mentioned, $\frac{1}{10000}$ of a grain of either of them can be recognized. As further illustrating the delicacy of microscopical tests, the alkaloid atropine may be mentioned. With bromine and bromhydric acid this substance yields peculiar crystals, which are characteristic in quantities of $\frac{1}{25000}$ of a grain.

Another important application of the microscope is in the identification of blood in stains, etc. The results of extended observations by the speaker relative to the subject will soon be published. The question presented to a microscopist when called upon to examine a stain may be in one of three forms, viz.: 1. Is it or is it not blood? 2. It is admitted to be blood, but what kind of blood? 3. It is admitted to be blood, and asserted to be blood of a mammal.

[1] Abstract of address prepared by the secretary of the section.

In the first instance the presence of blood can be recognized by the corpuscles. Serious mistakes have been made by persons who have been deceived by finding spores which they regarded as blood-cells. Three instances of this nature have occurred in this country within a few years. Such mistakes are not necessary, as it is always possible to distinguish blood-corpuscles. It may be claimed that the blood is that of a fowl. The form of the corpuscles will distinguish them from those of mammalian blood, but the corpuscles of cyclostomous fishes are circular.

In the second form of the question it becomes necessary to discriminate, if possible, between the blood of different mammals, especially to distinguish human blood from all other kinds. Some say this is possible, others that it is not. The discrimination depends upon the difference in size of the corpuscles and our ability to take cognizance of slight differences of this kind.

The speaker then discussed in an interesting manner the subject of minute measurements. The naked eye readily divides a space of $\frac{1}{100}$ of an inch into four parts. The oval blood-disks of *Amphiuma* measure $\frac{1}{450} \times \frac{1}{850}$ of an inch, and the naked eye readily notices the oval shape. But assuming $\frac{1}{100}$ of an inch as the limit of measurement with the naked eye, with a magnification of ten diameters the eye could measure $\frac{1}{100} \times 10$ or $\frac{1}{1000}$ of an inch with the same ease, or $\frac{1}{1000}$ with a power of 100 or $\frac{1}{10000}$ with a magnification of 1,000.

In measuring, the speaker prefers a Jackson eye-piece micrometer, and with this he finds $\frac{1}{1000}$ of an inch equivalent to 20 spaces of the eye-piece scale. Each space, therefore, represents $\frac{1}{20000}$ of an inch, and since a trained observer can readily divide the single spaces of the eye-piece into tenths, it is possible to measure the $\frac{1}{200000}$ of an inch, and by further magnification this limit may be reduced to $\frac{1}{500000}$ of an inch.

The difference in size of blood corpuscles is considerable; in the elephant they measure $\frac{1}{2700}$ inch, in the musk-deer $\frac{1}{12000}$. Blood-cells from some different animals have the same size. The corpuscles of human blood and those of several animals have practically the same dimensions. Those of the opossum, for instance, are about identical in size. Hence the microscope does not enable us to distinguish human blood in every case. The blood of the ox, which measures $\frac{1}{4000}$ inch, can be distinguished from human blood by the difference in size. It has been observed that the

blood-cells may become smaller than the normal size, but they never increase beyond it.

As regards the examination of blood-stains, it has been found that the corpuscles may be restored to their normal size after years of desiccation by digestion in fluids. The abnormal corpuscles are not likely to be restored. For this purpose the speaker prefers pure water alone. Some years ago a 33 per cent solution of potash was recommended. Water is now used, and the results are surprising.

The diameter of dogs' blood-corpuscles has been observed to be uniformly $\frac{1}{3500}$ of an inch, although prominent authorities have maintained that there was no difference between them and those of human blood.

At the conclusion of the address the Secretary inquired if drying affected the size of the cells, as had been asserted by some writers. In reply the speaker said he had never found any appreciable difference between the cells measured in the serum and when dried on a slide. The best method of spreading the blood on a slide for mounting was that of Professor Johnson. A drop of blood is placed on a slide and spread by drawing over it the edge of a second slide inclined. The smaller corpuscles to be observed in this way are abnormal ones, seldom found in the serum.

In response to a question by Mr. Hyatt, it was said the size of red corpuscles was not materially changed by diseases.

The range in size of human blood-cells was stated to be chiefly from $\frac{1}{3000}$ to $\frac{1}{3400}$ of an inch.

# PAPERS READ.

CELLOIDINE AS AN EMBEDDING MASS. By Prof. WILLIAM LIBBEY, jr., College of New Jersey, Princeton, N. J.

[ABSTRACT.]

CELLOIDINE is a pure form of pyroxiline manufactured by a patented process in Germany, and used largely in photography in place of collodion, and also for embedding purposes in histology. It is prepared by dissolving one ounce of celloidine in ether, noting the quantity of ether used, and when dissolved an equal quantity of absolute alcohol is added. Two solutions are needed, one very thin and the other thick.

The specimens, after being properly handled, are then soaked in absolute alcohol for an hour or two, then for the same period in strong ether, then for six hours in the thin solution and for the same time in the thick solution.

A good cork must also be soaked in some absolute alcohol, and when ready to embed, this cork is taken and a small quantity of the thick solution placed on one end of it and allowed to dry until it is well stiffened. Then the specimen, with as much of the thick solution as will adhere to it, is placed on this and allowed to dry partially, when another coating is placed over the specimen from the same solution, and this proceeding ought to be repeated until the specimen has a sufficient quantity around it to hold it firmly; then it is allowed to dry and when stiff is placed in 80 per cent alcohol for 12 hours at least before cutting.

The sections are best cut in alcohol and preserved in it until wanted. They can be stained as they are in the mass, as it does not stain readily, and then mounted, but they must be cleared up in oil of cedar or origanum, as the oil of cloves usually used dissolves the mass.

Where it is important to keep parts of the section in their relative positions, the above method of procedure is best, but where it is of no importance the mass can be removed perfectly by soaking first in absolute alcohol, then in ether for a few moments, and then putting them in alcohol again or in a mixture of equal parts of alcohol, glycerin, and water where they will keep indefinitely.

METHODS OF CULTIVATING MICRO-ORGANISMS. By GEORGE M. STERNBERG, M. D., Major and Surgeon, U. S. Army, Baltimore, Md.

[ABSTRACT.]

THAT branch of biological research which relates to the lowest and smallest of living organisms, the bacteria, or schizomycetes, is second in importance to none other, either from a purely scientific or from a practical point of view; for these lowly plants, in their morphology, growth, and reproduction, present to us the simplest possible conditions for the study of fundamental biological problems, and they offer peculiar advantages for the prosecution of experimental researches bearing upon these problems, by reason of their rapid multiplication and the facility with which species may be isolated and "pure cultures" maintained through many successive generations.

By means of these pure cultures we are enabled to study the modifying influences of environment upon form or function, the influence upon growth and reproduction of various chemical substances, of different degrees of temperature, etc.

It is only necessary to mention the brilliant discoveries of Pasteur and of Koch relating to the rôle of these minute plants in various processes of decomposition and in the etiology of infectious diseases, in order to call attention to the practical results which these researches promise.

Without doubt the very great accessions to our knowledge in this direction which have been made during the past few years are largely due to improvements in technique relating to the recognition (by staining reagents, special modes of illumination, etc.) and cultivation of the micro-organisms in question.

In a paper read at the Cincinnati meeting of this Association, in 1881, a detailed account was given of the writer's method of conducting culture experiments. Further experience has fully confirmed my conviction that the method referred to has advantages over all others for cultivating micro-organisms in fluid media, and my object at present is to give a practical demonstration by which the advantages claimed will be made apparent, rather than to add anything to the technical account of my mode of operating. At the same time I shall call attention to the invaluable method of surface cultivation, which is so highly recommended by Koch,

and which has been published by him since the reading of my paper above referred to.

The special advantages of each method will be pointed out, not with a view to showing that one is superior to the other, but in order to indicate the particular cases in which one or the other is preferable, for neither can entirely take the place of the other; and if a pure culture may be more easily maintained in an hermetically sealed flask, it is unquestionably true that the method of Koch has added greatly to our resources for the isolation and naked-eye recognition of the innumerable species of bacteria which surround us on every side, which infest the water we drink, the air we breathe, and, as harmless parasites, the human mouth and intestine in countless hosts and of many different forms.

It is only by resorting to some method by which we are able to secure and maintain "pure cultures" that we are able to obtain a precise knowledge of this extensive microscopic flora, for in nature the species are mingled together in such a way that nothing but confusion and uncertainty can come from the attempt to establish species upon morphological characters alone.

There is nothing novel in the form or construction of the little flasks which are used in the method which I recommend to you. They have, no doubt, been used occasionally by other experimenters for various purposes prior to my calling attention to their special advantages for the purpose in view. These advantages are best secured by making the flasks of moderate size, and by drawing out the neck into a slender capillary tube, so that the mode of manipulation which I shall demonstrate becomes practicable. The method, taken as a whole, is original, and, so far as I know, had not been practised by any one prior to the publication of my paper referred to. The usual method has been to use open-mouthed flasks or test-tubes, into which a sterilized culture-fluid is introduced, and from which atmospheric germs are excluded by a sterilized plug of cotton-wool. In skilful hands this method gives satisfactory results, but it requires much time and care, and the most experienced manipulators cannot avoid the occasional contamination of a culture, or the "breaking down" of a stock solution. Even if such accidents were not of common occurrence, the method I recommend would be preferable on the score of economy of time and material and of ease of manipulation. The advantages claimed, briefly stated, are as follows:—

The small flasks employed are made in the laboratory, from glass tubing, very expeditiously and at small expense.

Each flask contains a sufficient amount of nutrient fluid and of oxygen to insure a vigorous and abundant development of any aërobic micro-organism introduced as seed. The bacilli readily form spores in these flasks.

When properly sterilized, the enclosed culture-medium remains unchanged indefinitely, and the little flasks, ready for use at a moment's notice, may be packed away in drawers or boxes for years, if desired, and may be conveniently transported from place to place.

The inoculation of one flask with micro-organisms contained in another, or with a drop of blood from the veins of a living animal, etc., etc., is effected expeditiously and with perfect security from contamination by atmospheric germs.

Small amounts of fluid may at any time be withdrawn from one of these flasks for microscopic examination, without the slightest danger of introducing foreign organisms, and thus destroying the purity of the culture.

Finally, these little flasks take the place of a syringe when an inoculation experiment is to be performed, the contents, being forced beneath the skin, or into one of the cavities of a living animal, by applying gentle heat to the bulb, thus causing the enclosed air to expand, and forcing the fluid contents through the capillary neck of the flask.

The method having been described in detail in my paper already referred to (see report A. A. A. S. for 1881) my principal object at present is to give a practical demonstration of its advantages over other methods of cultivating micro-organisms in fluid media.

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REMARKS ON FLUID AND GELATINOUS MEDIA FOR CULTIVATING MICRO-ORGANISMS, WITH DESCRIPTION OF SALMON'S NEW CULTURE-TUBE AND DEMONSTRATIONS OF THE PROCESS OF USING IT. By Dr. THEOBALD SMITH, assistant of Dr. Salmon in the laboratory of the Bureau of Animal Industry, Department of Agriculture. (Read by ROMYN HITCHCOCK, Washington, D. C.)

[ABSTRACT.]

MUCH has been said of late concerning the advantages of a

solid substratum over a liquid medium in the culture of the Schizomycetes or so-called bacteria. This is no doubt due to its very successful employment by Dr. Koch, in the study of tuberculosis, and more recently, of cholera, and his own oft-repeated statements as to its superiority. He has, however, employed liquid media for his cultures of the tubercle-bacillus, and is now studying the comma-bacillus in a decoction of meat. In fact, he says that it flourishes best in fluids which do not contain too little nutrient material. (See *Deutsche Med. Wochenschrift*, 1884, p. 503.)

Many bacteria naturally live in fluids, such as the blood in case of disease, in stagnant water, etc. The life-history of such forms can never be traced completely without resorting to liquid cultures, approximating in chemical properties the natural medium of the microphytes. Thus, the swarming stage of bacteria can only assert itself in a fluid, and the peculiarity of many species to collect in the form of a membrane on the surface of liquids, at a certain period of their lives, can express itself only very indirectly or not at all upon a layer of gelatin or blood serum.

Though we must regard as an excellent addition in the study of bacteria the more rigorous technique of the present method of solid substrata, especially in its application to the isolation of different forms, it can never supplant liquid cultures, and therefore any apparatus which will materially simplify the laborious and minute technique, and reduce to a minimum the sources of error connected with the study of microscopic fungi in liquid media must be hailed as an important and lasting step in advance. The culture-tube, devised by Dr. D. E. Salmon, has certainly proved to be such. Though in constant use for over a year in his laboratory, Dr. Salmon has not yet found the opportunity of publishing an account of it, and owing to the pressure of official duties, his appearance at this meeting is impossible. I shall, therefore, take the liberty of pointing out, in the briefest manner, the construction and use of the culture-tube, with the hope that he will present a more extended description at a later date.

The culture-tube consists of a test-tube-like body or reservoir, of rather heavy glass, about 4 to 5 inches in length and three-fourths of an inch in internal diameter. Over the top of this reservoir a second hollow piece is fitted, which might be called a cap. Its internal surface is ground to fit snugly over the ground external surface of the upper end of the reservoir, thus forming

a ground-joint union. This cap, about 2½ inches long, abruptly contracts near its middle into a narrow tube with an internal diameter of about ⅜ of an inch. The third piece, which might be called the ventilating tube, is shaped like an inverted U, one limb being about 3 inches long, and 1½ inches longer than the limb which fits by means of a ground joint over the narrow tube of the cap. The longer, free limb of the ventilating tube lodges a plug of glass-wool from 1½ to 2 inches long. The limbs of the ventilating-tube are about one inch apart.

The culture-liquid is introduced by removing the cap, which brings with it the ventilating tube, and it is sterilized in the tube. The liquid is inoculated by removing the ventilating-tube only. To prevent the ground joints from sticking too firmly, a little sublimated vaseline is introduced between the surfaces of the joint.

The pipette, used to introduce a drop of fluid containing bacteria, consists of an ordinary glass tube about ¼ of an inch in diameter and 2 to 3 inches long, one end of which is drawn out into a very fine, almost a capillary tube, which must be long enough to easily reach the bottom of the reservoir when introduced through the narrow tube of the cap. A plug of glass-wool occupies the other end, which is closed by a rubber bulb.

The method of inoculating the culture-liquid is briefly as follows:—

The pipette is first thoroughly sterilized by flaming every portion of it from the tip of the capillary tube, to near the rubber bulb, until the contained air is subjected to a temperature of at least 150° C. We usually bring it to a dull red heat, avoiding the contingency of melting the capillary tube. It is hung with the rubber bulb up to avoid its capillary portion coming in contact with anything while cooling. When sufficiently cool, the capillary portion is again drawn once or twice through the flame to destroy any particles that may have become attached meanwhile. The ventilator of the culture tube, containing the bacteria to be sown, is flamed and removed and the narrow tube of the cap flamed, the rubber bulb slightly compressed, and the pipette introduced, a few drops drawn up, the pipette slowly withdrawn, the cap flamed again, and the ventilator replaced. The cap of the fresh tube is now flamed before and after removing the ventilator, the pipette introduced, a drop allowed to fall into the culture liquid, the pipette removed, the narrow tube of the cap again flamed, and the

ventilator replaced. This is the procedure of obtaining a pure culture from one preceding. When the source of the bacteria is an exudate, or a fluid of the animal body, various methods are in use. The method above given may, however, be employed in most cases.

The success of the work depends as much upon the worker as upon the materials employed. A bungling manipulation may cause failure with the best method. The personal equation in this, as in many other fields of research, is necessarily an important factor. Many minute details, which may seem too trivial to be mentioned, are slowly acquired, and gradually help to increase the percentage of absolute success.

It is evident that the reservoir may be variously modified. A flask-shaped body may be used for cultures that require an abundance of air, but the test-tube form will serve nearly all purposes. It enables the nature of the opacity in the liquid to be readily determined, while the earliest traces of a membrane or a deposit are more easily detected than with a broad body and a flat bottom. The microscopic appearance of these features, in case of many forms, will enable the experienced observer to foretell whether the culture is pure or contaminated.

The culture-tube, then, recommends itself as a simple, very neat apparatus, readily filled, sterilized and inoculated. It dispenses with the troublesome and dangerous expedients of disturbing cotton plugs, and of tying down various air-filtering materials. It is easily cleaned, and hence may be used over and over again, the original cost of the tube being in this way reduced to minimum in the end. It does not break readily, nor are there any sharp or jagged edges to be feared in the manipulation of dangerous cultures. It is very compact, and occupies but very little space in a thermostat. Finally, the chances of contamination through the air during the process of inoculation are practically of no account. We have not yet seen an impure culture derived from a preceding pure culture, during the period of our experience with these tubes. It is becoming more and more the conviction of careful investigators— and Brefeld, in describing his method, emphasizes it—that in a room where dust is carefully managed a short exposure to the air is not dangerous. The utensils used, upon which particles are continually being deposited, unless thoroughly sterilized, are the chief carriers of a miscellaneous contamination.

## Histology of Lingula. By H. G. Beyer, Surgeon U. S. A., Washington, D. C.

[ABSTRACT.]

It was only after considerable hesitation that I finally concluded, in a conversation with our esteemed secretary, Mr. Hitchcock, a few days ago, to venture making a few remarks on this subject, the pressure of my legitimate duties as naval medical officer having frequently interrupted my studies, and prevented me from presenting a more complete account, at least at present. I will, therefore, confine my remarks on those most interesting little organs called hearts, oviducts, and also segmental organs. These organs have attracted no little attention and interest on the part of the most distinguished anatomists ever since the time they first turned their attention to the study of the anatomy of the brachiopods in general.

Before the time when Hancock wrote his classical essay on the organization of the brachiopod in the *Phil. Trans.* of 1858, these organs had been described as hearts. Mr. Hancock, in the article referred to, says: "Four years ago I had occasion to dissect *Woldheimia australis*, *Terebratulina caput-serpentus*, and *Lingula anotina*, and was then struck with the peculiar appearance of the organs denominated hearts by Baron Cuvier and Professor Owen, all subsequent writers on the subject."

"These so-called hearts seemed to me very unlike any molluscan heart that had ever come under my observation, and on attentive examination it became evident that they give off no arteries, as they have been described to do; and, moreover, that their apices, from which the arteries were stated to pass off, appeared to open externally. For these and other reasons I was inclined to disbelieve in their cardiac nature, and to regard them rather as oviducts."

Hancock also discovered the true hearts, situated above the stomach, and two secondary pulsatile vesicles, situated somewhat posteriorly to the true heart.

These hearts, oviducts, or segmental organs (as they were called by Prof. E. S. Morse, who compared them to the segmental organs of annelids) are generally described as having two openings—one a small one externally, and another, large and funnel-shaped, opening in the perivisceral cavity.

I have brought with me a series of sections, by means of which

I hope to show you that although the opening to the exterior is very clear and manifest, the internal opening is not of so simple a nature as has hitherto been described. I find that the internal end is in very close relation and probable direct communication with the interior of a convoluted tubule or glandular sort of vesicle. These vesicles, two in number, are found on the looped portion of the alimentary canal, and so far as I am aware, and from what I have been able to gather from some of the plates accompanying the article by Mr. Albany Hancock, above referred to, correspond somewhat in situation to his pulsatile, secondary vesicles. On closer examination a communication was found to exist between these pulsatile vesicles and one of the diverticula of the alimentary canal, so that we have here an indirect communication between these oviducts and the lower portion of the alimentary canal. Until further and more extensive studies shall have been made on other brachiopods I shall abstain from entering into a discussion on the morphological significance of these findings. The specimens which I have brought with me to-day will, I hope, be sufficiently convincing, at least so far as Lingula is concerned. I shall present a more detailed account of the histology of Lingula at some future not very distant day. To-day I am obliged to limit myself to this brief and fragmentary account.[1]

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## Upon a microscopical method of studying the amphibian brain. By Dr. Henry F. Osborn, Princeton, N. J.

[ABSTRACT.]

The brain is hardened in bichromate of potash (Müller's fluid) the ventricles being fully injected. After the usual alcohol treatment, the brain is placed for one week in alum carmine solution; then for 24 hours in acetic acid.

The embedding mass is prepared by thoroughly shaking the contents of an egg with three drops of glycerine added. After soaking in this mass the brain is placed in position, and hardened

[1] Since this was written, further studies on the subject have convinced me of the fact that the above described condition was a pathological rather than a normal one.

in the vapor of boiling alcohol spirit, 80 per cent. The mass is then placed for one week in absolute alcohol.

The cutting is done with Jung's microtome; 50 or 60 sections collecting on the razor in alcohol are then floated at once, in order, upon the slide. To keep them in place they are covered with thin blotting-paper during alcohol and oil of cloves treatment. This is removed and the sections are mounted in the usual way.

The section glasses, and the sections showing particular structures, are then indexed.

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AN IMMERSION-APPARATUS FOR THE DETERMINATION OF THE TEMPERATURE OF THE CRITICAL POINT IN THE FLUID CAVITIES OF MINERALS. By Dr. ALEXIS A. JULIEN, Columbia College, New York.

[ABSTRACT.]

IN a former paper, read before the American Chemical Society, and published in vol. iii of its Journal, I have discussed the subject of the examination of carbon dioxide in the fluid cavities of the white topaz of Minas Geraes, Brazil, and took occasion to sum up the known occurrences of carbon dioxide in fluid enclosures of the rocks and veinstones of this country, so far as detected up to that time. The substance has been unfamiliar even to many chemists, and its occurrence in nature was considered rare, even by most geologists; but nineteen localities on this continent were then referred to, as determined by Messrs. G. W. Hawes, F. Zirkel, A. Wichmann, R. D. Irving, A. W. Wright, and, in four localities, by myself.

Reference was made to the various forms of stage-heating apparatus employed by observers to produce, in one of these minute cavities of a mineral, while under observation through the microscope, the rapid and extensive dilatation of the enclosed floating bubble or sudden vaporization of the liquid, by which the identification of carbon dioxide is easily effected, and to determine accurately the temperature at which this action takes place. This temperature may be very low, such as produced by the radiation of a burning cigar or of a warm metal rod, a jet of hot air or of

the warm breath conveyed through a rubber tube, or even of the tip of one's finger (32° C.) applied to the bottom of a thin slide, while resting upon the stage of the microscope, if the mineral section is also very thin. But the exact determination of the temperature at which the bubble or liquid disappears requires a special apparatus, of which several forms have been devised, which may be thus classed according to the thermal agency employed :—

1. A continuous current of hot air, conveyed horizontally through a metal chimney beneath the thin section and the adjacent bulb of a thermometer ; as in the several devices of Nachet, Beale, and Fuess.

2. A similar current of hot water conveyed between the stage and the slide and thermometer, through a metal conduit from a small adjacent tank or boiler ; as in the apparatus of Polallion, Ranvier, etc.

3. A conveyance of heat to the thin section and thermometer by conduction through a metal plate, preferably brass or copper, projecting beyond the stage over the flames of the tapers ; as arranged in the forms proposed by Chevalier, Dujardin, Ransom, and Schultze. (See Frey, "The Microscope.")

4. The conduction of heat derived from a galvanic current under the control of a rheostat, through a fine platinum wire bent back and forth over a ring-shaped thermometer bulb, upon which the slide is supported. This is the apparatus proposed by Vogelsang, fully described in most works on general lithology, as those of Zirkel, Rosenbusch, and Lasaulx, and even yet in common use.

The objection to all these forms of apparatus lies in their irregular application of heat, and its irregular and indefinite loss from currents in the surrounding atmosphere, and from the refrigerating effect of the mass of metal in the stage, and also in the microscope objective, in an amount proportionate to its close approximation, *i. e.*, to its focal distance or high power. Even in the most pretentious apparatus, that of Vogelsang, its inventor admits a variation or error of 10° C., according to the objective employed ; from a No. 4 Hartnack of 3 mm. focal distance to a No. 9 of 0.1 mm.

Vogelsang suggested the reduction of observations made by means of high-power objectives to the standard of the No. 4, and even was forced to make a plus correction of one degree (Centigrade) for observations in which the temperature of the air of the

room and of the microscope fell below his normal (20° C.) as far as 12° to 15°. Practically, in use these observations are consequently made almost altogether on large cavities and under low-power objectives, and an accuracy to one degree Centigrade has been accepted as satisfactory. Although wide discrepancies have constantly occurred, even in determination on the fluid cavities in the same slice of mineral, by means of these devices, on the other hand some of the most delicate and important investigations, such as those of Sorby and King on the indication of the degrees of pressure to which certain granytes have been subjected during folding and metamorphism, have rested largely upon the accuracy of determinations of this very kind. In my previous paper I have described two forms of apparatus, founded on the plan of immersion of both the objective and the thin section under examination in baths, which may be warmed sufficiently by the direct application of the flame of a taper, or by conduction through a copper plate, or by the slow addition of water of a different temperature, or, in a warm room, by a current of the observer's breath. All interference with the investigation, either by warm or cool atmospheric currents, or by radiation into or from adjacent metal, is eliminated by this plan. I afterwards found that the suggestion of the idea of immersion of the thin section alone had already occurred to Brewster, Vogelsang, Sorby and Hartley, who had in occasional single investigations simply immersed the mineral in heated water or glycerin, stirring up the liquid with a thermometer. The range of error, found in this partial application of the idea, amounted to 13° C., even with low-power objectives; the process was found tedious and slow, and Vogelsang preferred the use of his galvanic apparatus.

In place of the two forms of apparatus described in my former paper, I now present a more finished arrangement, consisting of a thin-walled box heated by conduction from a taper through the copper plate which forms its bottom and projects beyond the stage. The thermometer, made to order by the well known instrument maker to the Smithsonian,—Mr. Henry Green, of New York—has a scale ranging little beyond 22–45° C., each degree on the scale being two cms. in length and divided into tenths. The bore and length of the tube are so arranged as to bring that part of the scale near 30° C. on a level with the eye, while stationed at the eye-piece, to facilitate an instantaneous observation, by a

glance, of the height of the mercurial col
without a removal or even movement of th
fore that not only the high-power immersi
the $\frac{1}{18}$ of Spencer or $\frac{1}{8}$ of Powell and Lealan
way, but that apparently any low-power c
have their fittings water-tight, and can b(
mersed in the bath, only occasionally with
tion or brightness, sometimes with a de
both qualities, and with a complete dispens
for repeated refocussing otherwise required
the critical point in the fluid, checked by bc
disappearance and reappearance of the bu
fected in most cases within ten minutes, a
at least one-twentieth of a degree Centig
ther particulars and precautions, I need t
paper.

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ON SOME POINTS IN MICROTOMY. By JOHN
gist to the U. S. Fish Commission, W

[ABSTRACT.]

THE attention of investigators has bee
with this subject within a very recent peri
that a new art has been developed which w

In working with vertebrate materials,
should be done in such a way as not to dist
bryos, in order that the knife and microto
as to cut in any desired plane with accu
must be as homogeneous as possible; for t
the object with paraffin has been found t
evenly thin sections may be produced. Th
Plateau, Calbela, Duval, all serve this p
tive values are probably expressed in abc
they stand. Staining is best accomplished
by dyeing the object as a whole; this saves
in a number of ways. Mounting should
with the ribbon method; where hard paraf
are rapidly and easily laid on the slide wit

if the fixing is done with a compound of clove oil, three volumes, and collodion, one volume, which is thinly painted on the slide, and on which the sections are carefully laid, when the slide may be gently warmed for a minute; this melts the paraffin in the sections, the clove oil is driven off, and the sections fixed by the collodion, when a few drops of turpentine will immediately dissolve and remove the included and adherent paraffin, when the mounting may be done under an oblong cover in balsam.

These methods enable the student to interpret the structure of an organic body in three dimensions, and so great an accuracy of preparation is thus attainable that enlarged models are easily made from superimposed card or wax plates joined together and cut from outlines drawn by the help of the camera-lucida from the successive sections enlarged to a common scale; or it is even possible in the same manner to construct stereograms by drawing camera outlines one upon the other, for the reason that if the sections are properly prepared, every part will be in its proper place and the final result will be accurate. In this way I have built up views of embryo fish crania in perspective from one side; that is to say cartilaginous crania, which it would be utterly impossible to clean on account of their small size, so as to make an entirely serviceable preparation, because ordinary methods of preparing would inevitably shove important parts out of place and render the object unreliable for the purpose of illustration.

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RECENT STUDIES ON THE THEORY OF THE MICROSCOPE AND THEIR PRACTICAL RESULTS AS REGARDS THE USE OF THE MICROSCOPE IN SCIENTIFIC INVESTIGATIONS. By ROMYN HITCHCOCK, Washington, D. C.

[ABSTRACT.]

PROBABLY every observer of experience has a more or less clear recollection of the long and bitterly fought battle raged among microscopists, not many years ago, about angular aperture. There were advocates of wide or high angles, who believed the value of an objective increased for all purposes as the angular aperture was increased, independently of other consider

ations, and this view was advocated with all the steadfastness and vigor of such faith as would move mountains, had it been properly directed to that end. On the other hand, there was a more conservative but none the less vigorous party totally opposed to these views. The bitterness with which this controversy was carried on at times, year after year, is a blot upon the literature of the subject. But the differences of opinion arose, partly no doubt from stubbornness and erroneous observation, but mainly from want of knowledge concerning the subject. There was no recognition of a standard by which the value of an objective could be determined. It was a controversy, in fact, between those who believed in tests by resolving fine markings on diatoms, etc., and those who believed in clear definition of such objects as the podura scale. To be sure, other elements entered into the controversy, as, for instance, the question of the proper measurement of the angle of aperture, but the great question of interest to workers with the microscope was, What is the best objective for use—a wide or medium angle?

At the present time this question can be answered; but a few years ago it was a matter of opinion. The theory of the microscope then generally accepted was erroneous. The functions of angular aperture were in theory entirely misunderstood.

Let us endeavor to understand the subject in the light of recent investigations, for which we are mainly indebted to Prof. Dr. E. Abbe, of Jena, who has established a theory of the microscope, based upon experimental and mathematical investigations, which, in its essential features, if not throughout, seems as firmly established as any theory in optical science.

When an object marked with fine striæ, such as a diatom-shell, for example, or a glass plate ruled with lines and having the markings separated by spaces as minute as the wave-length of light, is illuminated in the ordinary way under the microscope, it is obvious that the light will be decomposed and a diffraction spectrum formed, precisely as in the case of Professor Rowland's beautifully ruled plates. Considering any single ray from the mirror, when it reaches such an object it will be turned from its direct course and pass off at an angle, forming a microscopic diffraction spectrum. This spectrum may be seen and examined in a manner to be described further on. First I must ask you to recall some old experiments given in text-books on physics. I refer to the inter-

ference bands of diffraction spectra. You will remember how the waves of light, when their vibrations come together in a certain manner, interfere with each other and produce lines of darkness due to overlapping spectra. I cannot go further into this subject here. The principle has been brought before you, and that is sufficient for the purpose in view. It must be clear to any one that if the light is thus turned from its course and decomposed, it cannot go on to form an image in the microscope as it was supposed to do according to the old theory of the microscope. It was then supposed that the microscope formed an image precisely as figured in works on physics in use at the present day, and in the same mannner as the telescope. Large objects, and outlines of objects generally, are imaged in this way; but obviously this cannot be true of the fine markings, closer than a wave-length of light.

Let us see what becomes of the diffracted rays forming the spectrum. Place a dry mounted specimen of *Pleurosigma formosum* under a microscope and examine it with a half-inch objective. When the markings are distinctly seen, remove the ocular and look down the tube of the microscope. There will be seen the diffraction spectra, just above the objective. Then put on the ocular and with a hand-lens examine the light which issues from it in the same way; there the same spectra will be found again. I will not attempt to explain how it is that these spectra are so combined in the image we see to produce the appearance of lines or dots as the case may be. The subject is too intricate to be easily understood; but the fact must be taken upon the authority of Professor Abbe and others, that the power of a microscope to define or resolve minute markings is absolutely dependent upon its capability of gathering in, and properly disposing of the spectra produced by the object.

We now come to the consideration of angular aperture. The cone of rays radiating from the focal point of the objective to the periphery of the front lens is the angular aperture—the angle of light it will receive. Suppose an object to produce a diffraction spectrum just beyond the range of a certain objective working in air. Interpose a refractive medium like glycerine or water between the object and the front lens. The rays which before were beyond the range of the objective are now brought, by refraction, to a smaller angular deviation, the spectrum is taken up by the objective and the markings are resolved. We can thus under-

stand the action and the advantages of immersion objectives. It has long been an axiom with microscopists that resolution of fine lines is dependent upon angular aperture; but in this case the immersion medium has materially lessened the angular aperture, while the resolving power of the lens is increased. Nevertheless, the angular aperture has been shown, under the conditions previously mentioned, to determine the resolving power. The apparent discrepancy here is easily explained, although it has caused interminable confusion in the past. The explanation in brief is this: angular apertures can only be compared under the same conditions. Thus angular apertures of objectives working dry, or objectives working in the same immersion fluid, can be compared among themselves, but those of one class cannot be compared with those of the other class. Thus a dry objective of 157° will resolve no more than one having an immersion angle in water of 94°, or in oil of 80°.

It will be seen that such comparisons are apt to be very confusing, and for this reason the term angular aperture might better be entirely discarded. A perfectly satisfactory method of designating the resolving power of an objective has been adopted by microscopists on the recommendation of Professor Abbe. It is by determining the "numerical aperture." In highly refractive media, the undulations of light become much shorter than in air, and as the capabilities of the microscope are dependent upon the wave-lengths, it is obvious that dense media for mounting add to the resolving power. Moreover, the visibility of an object is affected by the relation between the refractive indices of the object and the mounting medium. The more these differ the more visible the object will be. But time would not permit, even if it were desirable, a longer discussion of the optical action of mounting media of different refractive powers. Suffice it to say that Professor Abbe has shown, both by experiment and calculation, that the true aperture, distinguished when desirable as the numerical aperture of a microscope objective, which is the capacity of the objective to receive rays from an object to form an image, is the ratio between the focal length and the diameter of the back lens of an objective. This ratio will depend upon the refractive index of the medium of immersion, and is expressed by the product of the index of refraction multiplied by the line of half the angle of aperture for the particular immersion medium employed. This is expressed by the much-used formula $n \sin. u$.

The limit of resolving power has been calculated for different media and apertures, ranging from 1.52, which is theoretically the highest attainable, with an immersion medium of refraction index 1.52, since it corresponds to 180° of angular aperture in that medium, down to 0.50, and a table giving the figures is regularly published in the Am. Monthly Micr. Journal. The range of resolving power at present attained in practice scarcely exceeds 112,000 lines[1] to the inch, which should theoretically be attained with an aperture of 1.16, but the optical construction does not permit of the attainment of theoretical perfection. The highest numerical aperture to be obtained from the opticians is about 1.43.

We have already seen that there is a theoretical as well as practical limit to the power of a microscope to separate fine lines. This limit is determined first, by the numerical aperture of the objective and, secondly, by the magnifying power of objective and ocular combined, which in every case must be sufficient to separate the lines in the image until they subtend an angle large enough to enable the eye to distinguish them. This amplification attained, supposing the resolving power of the objective to be tested to its highest limit, no further amplification can possibly reveal any finer details in the image. Nevertheless, a slight increase is desirable to render the details more distinct, as all who work with delicate test-objects well know. There is, therefore, a well-defined relation between numerical aperture and amplification, which renders it possible to define the limits of adequate and desirable amplification for every objective. A recognition of this fact will show that the use of oculars of excessively short focal length, or high power, must be extremely limited in scientific investigation.

For the scientific student there is no device more generally useful than the Abbe illuminator, with its full complement of diaphragms. It is not strictly achromatic, but that is of no consequence. It is not costly compared with other forms, and is well adapted for universal use. It gives the observer complete control over the light, and is a great aid in all delicate observation. I feel like dwelling longer upon this subject to urge the use of this apparatus upon our scientific students. I am aware how many of them affect to despise all accessories. It is because they

[1] 120,000 has been claimed, but we are not satisfied with the evidence in support of this, rather improbable, accomplishment.

do not know their value. It will not do to say such things are of no use merely because they have not felt the need of them, for such persons do not know of what they speak. The true student of science should be quick to take advantage of every aid afforded by the optician's skill. As to the practical value of the Abbe condenser there can be but one opinion.

The use of polarized light in connection with the microscope is of great importance to the mineralogist, who is enabled to study the optical properties of minerals as they occur in rocks in microscopic quantities. The ordinary arrangements for polarized light serve well enough for such purposes and for the ordinary requirements of the microscopist. A far more elaborate and delicate apparatus for studying the optical properties of minute objects, is the polari-spectro-microscope of Rollet[2], or the spectro-polarizer of Zeiss[3] which serves the same purpose and can be attached to the ordinary microscope. Both these instruments consist of a polarizing prism, a dispersing prism to form a spectrum of the polarized light, and a plate of selenite. The different colors of the spectrum can be made to traverse the field of view in succession. The selenite produces dark bands of interference, the position of which depends upon the thickness of the selenite. An object possessing the slightest property of double refraction, such as a piece of muscle, for example, when placed in one of the dark bands, adds to the thickness of the selenite, and in certain azimuths, becomes luminous in the dark band. These instruments are, undoubtedly, the most delicate means we have of studying the optical properties of minute objects, and their value is enhanced by the ease with which the wave-lengths of the light used can be measured.

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DEMONSTRATION OF PERFORATIONS IN THE CELLULOSE WALLS OF PLANT-CELLS. By LOUIS ELSBERG,[1] M. D., New York, N. Y.

[ABSTRACT.]

Two years ago I communicated to the Section of Histology and Microscopy (Proceedings , vol. 31, p. 511) some investigations to prove the doctrine that the frame of cellulose, analogously to the

[2] Am. Monthly Micr. Journ., iv, 168. [3] Loc. cit., iv, 174.

[1] Dr. Elsberg died Feb. 19, 1885.—F. W. P.

cement substance of animal epithelia and the basis substance of other animal tissues, is pierced by either single filaments of living matter or a reticulum with more or less large accumulations of living matter, interconnecting all neighboring tissue-elements; and that the plant, therefore, like the animal, is one continuous mass of living matter, with interspaces which contain some non-living material.

This doctrine was hotly combated by the members present except the revered "master of American botany," Prof. Asa Gray; and a week ago, meeting him in Montreal, my attention was called by him to the fact that a number of observers have confirmed the doctrine more or less completely. Instances of protoplasmic continuity through cell-walls have been observed by Tangl[2] in the endosperm of certain seeds and by Gardiner[3] in "the pitted cells of the pulvinus of *Mimosa*, *Robinia* and *Amicia*." Frommann[4] had previously stated that he had been able to observe in various cases a continuous network extending from the protoplasm into the cell wall, and that protoplasmic nets pass from one cell to another and connect neighboring cells with one another by means of either smaller or larger gaps and crevices in the membrane. Strasburger holds the same view. Mr. Walter Gardiner, in an article entitled "Some recent researches on the continuity of the protoplasm through the walls of vegetable cells,"[5] makes some verbal criticisms on my paper which are well enough founded.[6] After describing some of his own experiments, he says[7] "My results, then, agree with those of Dr. Elsberg in so far as the reticulate structure of chlorophyll grains is concerned, but I have been unable to trace any reticulation in the protoplasm itself." His silver nitrate preparations, he says, "exhibited a structure somewhat similar to the figure drawn by Dr. Elsberg, viz., that on the cut surfaces of the cell walls were a number of exceedingly small, darkly-stained patches, separated from one another by light and unstained narrow areas." But this appearance, according to him, "is simply due to

[2] Pringsheim, Jahrbücher, f. wiss. Bot., 1880, vol. XII, pp. 170—90.

[3] Quarterly Journal of Microscopical Science, October, 1882.

[4] Beobachtungen über Structur. u. Bewegungserscheinungen des Protoplasma der Pflanzenzellen. Jena, 1880.

[5] Quarterly Journ. of Micr. Science, April, 1883, p. 302 *et seq*.

[6] He points out that *Nierembergia* is printed "Novembergia" and he might have pointed out more glaring typographical errors due to the fact that I had no opportunity to read proof-sheets.

[7] Loc. cit. p. 308.

the fact that granules of reduced silver are deposited on the cut surface of the cell walls, and that no staining occurs in the substance of the wall itself. The whole appearance of protoplasmic continuity can be brushed away by mere mechanical means, and the size of the granules can be varied at will. The reduction of the silver in the cell wall is caused by some of the cell contents which have escaped from the cell lumen," and the particular reducing substance, he thinks, is tannin. Altogether so far as his investigations have progressed, he says that "there has not only not been the least suggestion of the presence of large quantities of protoplasm in the cell wall, but also that no examples of reticulate arrangement have been met with in those cases where perforation actually takes place." Frommann in his latest publication[8] upholds against Gardiner the correctness of his own previous observations.

I am about to submit to you a demonstration of perforations in cellulose to which Gardiner's explanation of silver reduction by the presence of tannin and silver nitrates certainly does not apply. But first let me cite the opinions of two other investigators, viz. F. O. Bower and T. Hick.

Bower[9] considers that it has now been demonstrated with as much certainty as is possible, by the use of microchemical and staining reagents, that in certain cases, the number of which is now constantly being increased, there is a direct connection between the protoplasmic bodies on opposite sides of cell walls, and that this connection is established by means of fine strings of protoplasm which, in the cases observed, run nearly transversely through the walls.

Hick[10] has made an extensive series of observations on a large number of species belonging to the more important genera of Florideæ, with special reference to the question of protoplasmic continuity. He finds in all the species examined that there is such a continuity and that of the clearest and most definite character In the simpler filamentous types, such as *Petrocelis cruenta* and *Callithamnion Rothii*, the protoplasm of each cell is united with the protoplasm of contiguous cells by means of a fine protoplasmic thread This occurs throughout the whole plant. In the more complex types, such as *Callithamnion roseum*, *arbuscula*, and *tetragonum*

[8] "Untersuchungen über Struktur, Lebenserscheinungen und Reaktionen thierischer und pflanzlicher Zellen." Jenaische Zeitschrift für Naturwissenschaft. Bd. XVII. N.F. Bd. Jena, 1884.

[9] Journal Roy. Micr. Soc. Feb., 1884, p. 75.

[10] Ibid, p. 101.

the arrangements for continuity are of a more elaborate character. The contents of the axial cells are not only united with one another, but also with those of the cortical cells, however numerous these may be. The cortical cells also display continuity *inter se*. *Ptilota elegans* is a most instructive form, as here the connective threads may be easily traced from the tips of the ultimate branchlets to the base of the stipes of the frond. As the threads become older, they increase in thickness, thus showing that they are not merely temporary or effete structures. On the stouter connecting cords, a sort of ring or collar is developed at about the middle point, and over this is stretched, in some cases, a delicate diaphragm. The behavior of both rings and diaphragm, when treated with microchemical reagents, is similar to that of ordinary protoplasm.

The view that I hold of the structure of plant tissue may very well be illustrated by reference to the structure of hyaline cartilage. Formerly cartilage was believed to consist of a homogeneous non-living basis-substance in which are embedded, at various distances apart, isolated, living cartilage corpuscles, the so-called cartilage cells; now cartilage is known to be a filigree of living matter in the meshes of which, lumps of basis-substance are embedded. To use a homely simile, if you imagine a peculiar raisin-cake, in which the raisins represent the living matter and hardened dough the non-living, the former view would involve dough in which a certain number of raisins are embedded; the present, a framework composed of larger and smaller raisins and bands and strings of raisin-substance, in the meshes or interspaces of which framework blocks of hardened dough are embedded. Just so in the tissue of plants, the so-called plant-cells are connected one with the other, and blocks of cellulose fill up the interstices in the network of living matter.

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ON SOME NEW MICROSCOPICAL DEVICES. By Dr. R. H. WARD, Troy, N. Y.

[ABSTRACT.]

IT is proposed to describe the following new forms of microscopical apparatus:

(*a*) A new illuminating arrangement called the Iris Illuminator, which consists of an Iris diaphragm with decentering adjustment, combined with an Abbe Illuminator, or other condensing system of lenses, in such a manner that the illuminating pencil of

light can be accurately graduated not only in an axial but also in an oblique direction.

(*b*) A new lens-holder, with long arm and with fine adjustment; with which magnifying lenses of either low or high power can be firmly supported and accurately focussed at sufficient distance from the supporting pillar to be used in examining mounted herbarium specimens or other objects widely distributed on the laboratory table.

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DESCRIPTION OF THE SCHRÖDER CAMERA LUCIDA. By R. HITCHCOCK, Washington, D. C.

[ABSTRACT.]

THE construction of this instrument was described and the manner of using it illustrated. The author stated that it was, in his opinion, superior to any other form of camera lucida, in that the point of the pencil could be distinctly seen, even when the illumination of object and paper was not carefully adjusted. The pupil of the eye is not divided over a reflecting prism, as in the instrument with two prisms by Zeiss, but considerable latitude in the position of the eye is allowed. The field of view is large and the image of the object is seen projected well out from the foot of the microscope. The pencil is seen directly, the image of the object by reflection. The principle is an adaptation of the binocular prism devised by Mr. F. H. Wenham for use with high-power objectives.

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ON THE REPRODUCTION OF SHORT STANDARDS OF LENGTH. By Prof. WM. A. ROGERS, Harvard College Observatory, Cambridge, Mass.

[ABSTRACT.]

DESCRIPTION of the various steps by which a centimeter or an inch may be produced from a standard metre or a standard yard.

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ELECTRIC ILLUMINATION FOR MICROSCOPE, WITH PRACTICAL ILLUSTRATION. By W. H. WALMSLEY, Philadelphia, Pa.

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# SECTION H.

# ANTHROPOLOGY.

# ADDRESS

BY

## PROFESSOR EDWARD S. MORSE,

VICE PRESIDENT, SECTION H, ANTHROPOLOGY.

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## *MAN IN THE TERTIARIES.*

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MAN, profoundly interested in his origin and antiquity, finds himself hampered in his investigations by the opinions and prejudices that have grown up with him. He finds it well-nigh impossible to step outside of himself and regard himself as a mammal among hundreds of other species of mammals.

The formidable dogmas which he has erected, and perpetuated through centuries, to explain his origin, have become obstructive barriers which have had to be assailed, one after the other, to clear the way for rational investigation. The arrogance, fury and final desperation of their defence have been only faintly portrayed by history.

The most formidable, and indeed the chief, of these barriers was the one interwoven with theological dogma. Its foundation was laid fifteen centuries ago, and each century added its accumulations, until, finally, by violence and otherwise, it became a part of man's inheritance, to assail which was to imperil his most cherished convictions. With the partial removal of these barriers, one becomes mindful of the precious evidences of man's antiquity, which have been overlooked, or forever lost; evidences all the more precious because so difficult to obtain.

These barriers being no longer obstructive, others arose, having for their foundation evidence, and having for their builders men who belonged to that class which had been mainly instrumental in clearing the ground of previous obstacles.

The most important of these barriers was the one erected by Cuvier in the declaration that man being the last and highest

creation, and intimately associated with the present fauna, could never have been contemporary with the extinct species of mammals found in the quaternary beds. Fortified by this barrier, science repelled for a time all evidences brought forward to show that man's remains were synchronous with those of extinct mammals, and the authors of these evidences were treated with neglect and even ignominy.

The assaults of this barrier are now historic. The final and triumphant vindication of Perthes, Schmerling and others, and the consequent overthrow of Cuvier's massive authority in this matter, are familiar to every student of archæology.

No sooner had the Cuvierian barrier against quaternary man been demolished, than smaller barriers of precisely the same nature were erected against tertiary man.

Gaudry, while admitting the authenticity of the worked flints, discovered by the Abbé Bourgeois in the miocene of Thenay, could not admit that they were those of man, because he says, "There was not in the middle of the miocene epoch a single species now extant. Considering the question from a palæontological point of view it is difficult to believe that the flint carvers of Thenay remained uninfluenced by this universal change."

Professor Dawkins[1] in a similar line of argument assumes that "man, the most highly specialized form in the animal kingdom, cannot be looked for until the lower animals by which he is now surrounded made their appearance. We cannot imagine him to have been living in the eocene age when animal life was not sufficiently differentiated to present us with living genera of placental mammals. Nor is there any probability of his having appeared on the earth in the miocene, because of the absence of placental mammals belonging to living species. It is most unlikely that man should appear in a fauna in which there was no other living mammal.

"He belongs to a more advanced stage of evolution than that presented by the mid-miocene of Thenay, in which flint splinters fashioned by man are said to have occurred. Up to this time the evolution of the animal kingdom had advanced no farther than the *Simiadæ* in the direction of man, and the apes then haunting the forests of Italy, France and Germany were the most highly organized types. We may also look at the question from another point of

[1] N. A. Review, Vol. 137, No. 4.

view. If man were upon the earth in the miocene age, it is incredible that he should not have become something else while those changes were going on in the conditions of life by which all the miocene land mammalia have been so profoundly affected that they have either assumed new forms or been exterminated. It is impossible to believe that man should have been an exception to the law of change," and for similar reasons Professor Dawkins says we cannot expect to find traces of man in the pliocene age. The student fully imbued with these opinions, the same in kind with those of Gaudry, is inclined to repudiate or modify the interpretations of all evidences bearing on man's existence before the quaternary.

That such barriers are really obstructive is plainly evident. In thus authoritatively setting a limit to man's antiquity a check is not only put upon research but, if firmly grounded in the minds of some, evidence, if met with, is mistaken or ignored.

The history of palæontology is strewn with these barriers, barriers not only limiting groups of animals to certain horizons, but repeatedly placing a limit to the dawn of life itself. How well do we recall the timeworn geological terms characterizing the different geological periods as they were recognized in our younger days, and how many thousands of vertical feet have been recovered from the Azoic and brought into orderly sequence, defined by names which are getting to be equally familiar.

As the objections to the occurrence of man in the tertiaries are in every case purely theoretical, they may, with perfect fairness, be combated on theoretical grounds.

In the theological barrier the objection to man's high antiquity rested solely on the fact that it was in direct conflict with Mosaic cosmogony, and yet this barrier, unsupported by the faintest scrap of evidence, thwarted the study of man's antiquity up to within very recent years.

In the Cuvierian barrier man was assumed to be structurally the highest mammal, and consequently must have appeared last.

In the analogous barriers of Gaudry, Dawkins and others, the assumption is that since orders, families and genera have become extinct, it is inconceivable that man should have remained unchanged while those profound modifications and extinctions were going on.

This position has been greatly strengthened by the idea that

man has been evolved from the higher apes, and that his nearest relations among these creatures are those which are supposed to have appeared last in the sequence. The troublesome fact, however, confronts us that we find the evidences of man associated with extinct apes, and the gap between them is by no means closed in these earlier horizons.

Assuming that man has sprung from the same stem with the higher apes, and assuming, moreover, that he is limited to the quaternary, we do not find in the earlier deposits what we should have a right to expect, namely, generalized forms of man, that is, creatures that while markedly ape-like in character were unquestionably man. In the earliest remains of man, thus far recognized, we do have the most pronounced ape-like features, as in the well-known Engis and Neanderthal, and in the more recently discovered Tilbury and Podhaba skulls. But all these forms are still man, with a fair brain case whatever may be inferred regarding the depth and number of his cerebral convolutions. The modifications toward an ape-like structure, slight as they may appear, have the deepest significance in clearly indicating the direction from which he sprang.

If palæontologists are right the first anthropoid ape has been found in the middle eocene, and later still a more generalized form called Oreopithecus which, according to Gervais, had affinities with the anthropoid apes, macaques and baboons. Side by side with these early apes are found chipped flints, if we are to accept the authority of their discoverer, Bourgeois, and the opinion of Mortillet and others.

If man existed then, and on theoretical grounds there is no reason to believe that he did not exist, where are we to look for the approach of these two groups? Surely far beyond the limits where these evidences had hitherto been found. We must not be content to trace out the evidences of man in his work, for before the rudest flint was fashioned by him he must have used natural fragments of sticks and stones, and even this faculty must have indicated an advance far beyond that of his progenitors, who had not acquired even the habit of handling weapons. The earliest evidences must be sought for in his remains, and not in his works, and here we meet with a difficulty which unfortunately not only accompanies the remains of man and those creatures having an affinity with him, but of other groups of animals as well; condi-

tions which have rendered the preservation of their remains a matter of chance; conditions duly recognized by palæontologists pertaining to their perishable nature, life habits or the composition of the rocks in which such and such forms must of necessity have occurred. While the remains of certain groups of animals are scattered through the rocks in the greatest profusion, of other groups, perhaps equally numerous in individuals, the scantiest traces are met with. The very conditions of life which characterized early man and his associates render the preservation of their remains a matter of extreme improbability. The herbivora, in herds, seeking the shelter of watery places to avoid heat and insect annoyances would, in dying, become mired, and thus preserved in a matrix for the future explorer. The heavier mammals, like the mastodon, would become engulfed by their own weight under conditions which would preserve them, and these are not suppositious cases, but in accordance with facts connected with their discovery and preservation. Aquatic forms are infinitely more abundant as fossils than land or aërial forms. Professor Marsh, in his monograph on the fossil-toothed birds of America, testifies to the extreme rarity of the remains of land birds over those of aquatic habits.

The arboreal ancestors of man, and the probable habits of man himself, would leave their bones to bleach in the field or forest, to decompose and disappear long before an entombment were possible. It was only when man acquired the art of sepulture or sought refuge in caves that the preservation of his remains became assured.

Even after man sought the shelter of caves or acquired the art of burial, surface changes have been so widespread and profound as nearly to obliterate all evidences of those places. Professor Dawkins, the eminent archæologist and geologist, says that while there have been caverns in all geological periods, they have all been obliterated by "the rain, the alternations of heat and cold, the acids evolved from decaying vegetation and the breakers on the seashore," and this abrasion and destruction have been so extensive and thorough that Professor Dawkins recalls only two caverns that can be said to be as old as the middle pliocene.

Even when these caves have been preserved, the harvest from them has been of the most meagre description.

Schmerling, who examined nearly fifty caves in Belgium, found

human remains in only two or three of them. Lund, who examined eight hundred caves in Brazil, found only six containing human remains. It would seem as if the elements had conspired to efface every record of that creature who alone takes any interest in his own origin. We survey large areas rich in the works of man, yet find no traces of bones of man himself. The Swiss lake-dwellers we know minutely from the *débris* of their ruined villages, grain and even the bread they made being preserved; and yet human bones are of scanty occurrence. The Danish peat-beds have as yet never yielded human bones, though stone implements and objects of various kinds from these deposits enrich the museums of Denmark.

The shell heap deposits all over the world rarely contain human bones. It is said that none have been found in the Danish shell heaps, though Wyman found a few in the Florida shell mounds, and the deposits in Japan reveal similar traces.

Chief among the agencies in destroying the evidences of man have been the glacial floods, and these, if the glacialists are right, have occurred, one, during the earlier pliocene, and the other at the beginning of the quaternary. To these overwhelming and annihilating ice torrents, grinding, sweeping and inundating the north temperate zone, must be attributed the almost complete obliteration of records we hold most precious; and in their gradual recedence no less destructive agencies were at work in scooping out valleys, inundating immense areas and covering broad tracts of land by their detritus.

Even man to-day with his colossal works of engineering skill would in the face of a glacial flood yield the last traces of the evidences of his existence. A few corroded bowlders of metal and bits of glazed pottery alone might survive. What must such a torrent have been to primitive man with his simple and rude appliances!

It would seem from many facts that early man lived in the vicinity of water, either on the banks of rivers, or along the coast line. The reasons for this are obvious enough; food was always procurable at every receding tide and when man acquired the art of boat-making, natural thoroughfares were always available and of greater necessity from the dense forests which covered the land.

Now it is just these regions that have been most profoundly modified since glacial days and indeed in all times.

Ancient river beds have been widened, lowered and obliterated, coast lines have changed, great tracts have disappeared beneath the waves and degradations of the coast lines by the pounding of the waves have been universal.

Professor George H. Cook, state geologist of New Jersey, calls attention to the universal subsidence of the coast line from the Carolinas to Greenland. The erosion of all the shores and islands along the coast of New England is very marked. Shell heaps are everywhere met with, cropping out and crumbling down with the decaying banks, and the records of man thus lost can never be regained.

If Saporta's idea is correct then, of course, the traces of these primitive people are buried under paleochrystic ice. Saporta suggested the idea that man, originating in the north, had been pushed southward by successive waves of people till the primitive wave was forced into the extremities of the southern continents, and that the remnants of this ancient wave are seen in the Tasmanians, Bushmen and Fuegans.

That such a wave could be forced the length of the world, through such vicissitudes of climate and accompanying conditions, unmixed and unbroken, seems incredible. Far more probable would it be to assume an antarctic continent under genial conditions in which these primitive races lived, I will not say originated, and whence successive waves emanated, becoming modified by their new surroundings as they receded from their point of origin. The submergence of this region leaving remnants of these extraordinary, low and uniformly dolichocephalic types as we recognize them in the Patagonians, Tasmanians, Australians, Bushmen, Veddahs and others, and precisely where we might expect to find them. If either supposition is true the earlier traces of these people are forever buried beyond recovery.

In the face of all this destruction and effacement must be reckoned also the prejudices of man himself, which have caused the loss of precious material, or of opportunities which can never be regained. Ancient skeletons have been exhumed only to be promptly buried again; others encountered in excavations and left undisturbed through superstitious fear. Even at the present time the recognition of all evidences bearing on the high antiquity of man is checked by a scrutiny that oftentimes becomes well-nigh ridiculous. The collection and study of the remains of other fossil

mammals go on unchallenged. Material is collected and allotted to its proper horizon without dispute. The archæologist, however, is beset by a class who repudiate his facts, look upon his evidences as deceptive or fraudulent, and within very recent times have not hesitated to apply terms of equal opprobrium to the investigators of these things.

We are continually warned that caution should be exercised in accepting evidence not verified by scientific observers; at the same time we should be on our guard to repudiate all protests against the high antiquity of man made by those not equally well informed.

From the preceding pages it is evident that the discovery of the remains of early man, or rather of primitive man, is highly improbable. Nevertheless we need not despair; other forms of animals have been equally rare for a time until some unlooked-for discovery has brought to light a rich mine of material. Until this good fortune comes to us we must be content to reason from the known to the unknown.

In regard to the physical characteristics of man, it has been wondered by Gaudry that man could have remained unchanged while so many other forms have been modified or become extinct. That slight changes in the osteological structure of man have taken place he must admit, and that mammals of huge form and great variety have become extinct, and others profoundly modified since his appearance, are equally certain.

These facts he recognizes so far as pleistocene man is concerned, but the great disproportion in the changes that man may have undergone, and the known changes of other mammals since miocene days, seem too improbable to be accepted. On the other hand, it seems reasonable to believe that the moment the ancestors of man possessed the power of banding together in communities and of using weapons, they became capable of rendering inoperative the very influences which were so active in modifying or exterminating their mammalian associates.

How far these conditions were settled in the quaternary may be seen in the fact that while man could endure an arctic climate, his anthropoid and more distant pithicoid relations bathed in a tropical heat. Indeed, the latter disappeared from Europe forever on the approach of the cold wave, while man survived.

The fact that man and his near associates have been regarded

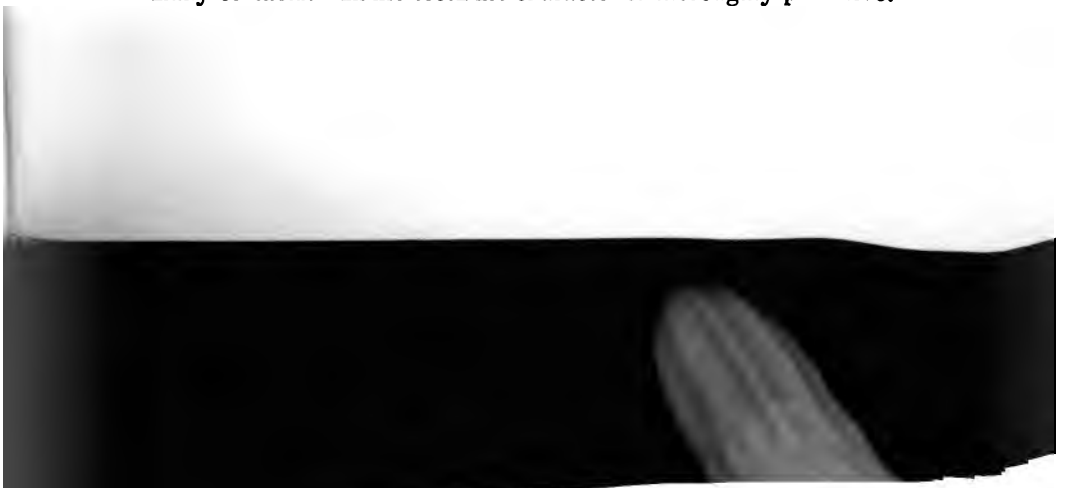
as, structurally, the highest forms of mammals, has led to the natural belief that they must have been last evolved.

That man is preëminently the highest form intellectually goes without the saying. In the words of Topinard, "The supremacy which our very exalted intellectual faculties secure to us, is confirmed to us by the existence of an exceptional development of the organ which is its seat." Man has three or four times more brain than the highest ape. This excessive disproportion, even taking the capacity of the earliest crania, must presuppose a long line of ancestors in which this capacity was less and less.

The same progress that man and his near relatives have shown, in an unparalleled degree in the development of the brain, is also remarkably conspicuous in other mammals and vertebrates lower down in the scale, as shown so admirably by Marsh.

The size of the brain case went on increasing from the earlier to the later geological periods out of all proportion to other modifications of structure.

In relation to this subject it seems that sufficient importance has never been given to the generalizations of Cope wherein he considers the relations of man with tertiary mammals; and until sufficient recognition has been accorded to these generalizations I feel justified in again bringing them forward. In these considerations Professor Cope shows that "the mammals of the lower eocene exhibit a greater percentage of types that walk on the soles of their feet, while the successive periods exhibit an increasing number of those that walk on the toes, while the hoofed animals and Carnivora of recent times nearly all have the heel high in the air, the principal exceptions being the elephant and bear families." He then calls attention to the progressive osteological changes of the foot from the earlier to the later types through several lines of descent, and says: "The relation of man to this history is highly interesting. Thus, in all generalized points, his limbs are those of a primitive type so common in the eocene. He is plantigrade; has five toes; separate tarsals and carpals; short heel; flat astragalus, and neither hoofs nor claws, but something between the two: the bones of the forearm and leg are not so unequal as in the higher types, and remain entirely distinct from each other, and the ankle joint is not so perfect as in many of them. In his teeth his character is thoroughly primitive.



* * * His structural superiority consists solely in the complexity and size of the brain. A very important lesson is derived from these and kindred facts. The monkeys were anticipated in the greater fields of the world's activity by more powerful rivals. The ancestors of the ungulates held the fields and the swamps, and the Carnivora, driven by hunger, learned the arts and cruelties of the chase. The weaker ancestors of the quadrumana possessed neither speed nor weapons of offence or defence, and nothing but an arboreal life was left them, when they developed the prehensile powers of the feet. Their digestive system unspecialized, their food various, their life the price of ceaseless vigilance, no wonder that their inquisitiveness and wakefulness were stimulated and developed, which is the condition of progressive intelligence." And Professor Fiske shows, on other grounds, that when variations in intelligence became more important than variations in physical structure, they were seized upon to the relative exclusion of the latter.

I am not aware that these postulates have ever been gainsaid, and their admission answers the objections urged by Gaudry and others, and explains on rational grounds why man has continued to persist for so long a time with physical characteristics so slightly modified, while other forms were changing or becoming extinct.

As to his structural affinities with the higher apes, it has been shown that his relations are not only with these forms but scattered through the whole range from the gorilla down, and osteologically even with the half-apes, the lemuroids, and these in turn have affinities with those perplexing forms, the aye-aye and tarsier.

As to his osteological affinities with the Lemuroidæ, insisted upon by Mivart, it is worthy of note that these forms have been discovered in the lower eocene of both continents.

If these structural affinities are valid, then we must look far beyond and below the present higher apes for the diverging branches of man's ancestry. Among the many evidences of the early origin of man is the one that reveals the early establishment of well marked types which must have required an enormous lapse of time to have established. Repeatedly the evidences are brought forward, by different investigators, that the various types of skulls are met with among the earliest traces of man.

Without mentioning the comparatively recently lake-dwellers of Switzerland, among whom Dr. His believes he has discovered four different types of skulls, we turn to the labors of Professor Kollman, who has made an exhaustive study of the crania of various races in both hemispheres. The results of these studies have established the existence of races of people bearing certain unchangeable characters so far back as the remains of man have been detected. Among those races living to-day he calls attention to the Malay and Papuan existing for so long a time under similar tropical influences, and yet so markedly different in their racial characters.

From a study of the skulls, both ancient and modern, of the native races of North and South America, as well as those of other parts of the world, Dr. Kollman comes to the opinion that the sub-species of man became fixed in the preglacial period, and through the vicissitudes of time a greater or less influence has been exerted upon varieties in different areas.

Mr. Keane, in the Journal of the Anthropological Institute for February, 1880, shows that the great Asiatic types, known as the Caucasian and Mongolian, have from prehistoric times occupied the Chinese peninsula. And these evidences are continually multiplying, not only in regard to the diversity of type among early races, but to their equally wide dispersion as well.

Furthermore, the evidences go to show that early man had become sufficiently differentiated to acclimate himself to widely different regions of the earth's surface, ranging from the torrid to the arctic, while the apes were still confined to the torrid zone. The remains of his feasts show that he had early become omnivorous.

These facts in themselves indicate a wide gap then separating man from the higher apes, and add further reason for his ability to remain unaltered amid the universal change going on about him.

The most powerful argument, in favor of the belief that man must have existed in the tertiaries, lies in the very important fact that his earliest remains are not confined to any one region of the earth which might have been a centre of distribution—a paleolithic garden of Eden—but are found in all four quarters of the earth, as the rapidly multiplying evidences are testifying.

To go no farther back than the river-drift men, if, with Dawkins, we admit that these are the first reliable traces of man, we find that these people were not confined to any one special region of the earth's crust, but, on the contrary, are found impartially scattered from tropical India, through Europe, to the continent of North America. They could not have been distributed through the northern approaches of the continents unless this distribution occurred in preglacial times, because, as Dawkins shows, an ice-barrier must have spanned the great oceans in northern latitudes.

It seems an almost fruitless speculation to inquire into the manner of their dispersion, yet one is tempted to surmise that if they originated in the tropics, then submerged continents must be restored to offer the means necessary for such a dispersal. If, on the other hand, their home was in the north or south temperate zone, and the distribution circumpolar, which seems more probable, then we have another evidence of the wide separation which the race had undergone, at that early day, from its tropical relatives, the apes. Whatever the facts may ultimately show, this unparalleled distribution of a people in the lowest stages of savagery proves beyond question that man must have preëxisted for an immense period of time, for, with the known fixity of low savage tribes, the time required to disperse this people over the whole earth can only be measured by geological centuries.

The farther we penetrate into the past, and ascertain some definite horizon of man's occurrence, other observers in widely different regions of the earth bring to light traces of man's existence in equally low horizons. The remoteness of man's existence in time and space is so vast that, to borrow an astronomical term, no parallax has thus far been established by which we can even faintly approximate the distance of the horizon in which he first appeared. By this fact we are justified in the assumption that the progenitors of quaternary man, under different genera possibly, must be sought for in the tertiaries.

Science will not gain by the erection of any theoretical barriers against tertiary man, until such definite forms are met with as shall reasonably settle the beds in which he first occurred.

We know in what rocks it would be obviously absurd to look for his remains or the remains of any mammal. So long, however, as forms are found, in the lowest beds of the tertiaries, hav-

ing the remotest affinity to his order, we must not cease our care in scanning unbiassed, even the rocks of this horizon, for traces of that creature who until within a few short years was regarded as five thousand, eight hundred and some odd years old, and who despite of protest and prejudice has asserted his claim to an antiquity so great and a dispersion so profound that thus far no tendency to a convergence of his earliest traces has been demonstrated.

# PAPERS READ.

## The occurrence of man in the Upper Miocene of Nebraska, By Prof. Edward D. Cope, Philadelphia, Pa.

[ABSTRACT.]

A last superior molar tooth of an Anthropoid, perhaps of the genus Homo, was found by Mr. F. H. Hazard in a bed of loose calcareous sand in southern Nebraska, in company with fossils of undoubtedly Loup Fork or Upper Miocene age. These fossils are *Castor pansus* Cope, belonging to the extinct section of the genus called *Steneofiber; Mylagaulus monodon*, an extinct genus allied to the *Agutis*, and some other bones.

The mineral condition and surface erosion of these specimens are identical, and as far as appearances go, and were not one of them so like the molar of man, no one would dispute their contemporaneity. But the matrix was of soft consistence, so that the actual horizon of the tooth cannot be positively fixed.

## Exhibition and description of some palæolithic quartz implements from central Minnesota. By Miss Franc E. Babbitt, Little Falls, Minn.

[ABSTRACT.]

The Little Falls quartz implements here exhibited[1] are to the last degree primitive, in the matter of shaping and finishing; the former of these two processes having been largely accomplished by means of flaking, and the latter, by pecking and rasping. By flaking is meant, of course, the successive detachment, from the piece undergoing manufacture, of relatively large patches of superfluous material, and by rasping, the removal by attrition of troublesome asperities upon the surfaces of such pieces. Both these styles of handiwork appear to have been executed with a convenient bit

[1]The specimens exhibited before the section are now in the Peabody Museum at Cambridge, Mass., where they can be seen by any one interested.

of quartz, which was shaped into a tool by human hands, or used without shaping, according to the particular conditions of the case.

These quartzes are consequently not chipped, in the ordinary acceptation of the term: and they may, when singly examined, very well be mistaken by the unpractised observer for capricious products of natural agencies. In studying full series of quartzes identical in type, however, one may usually distinguish, among implements variously worn by usage, and others unmistakably incomplete, some one or two which are perfect in their way, and therefore typical, and which, furnishing a standard of comparison for broken and unfinished specimens, serve as a key to the whole group. The inspection of a suite of such implements thus affords the archæologist a sense of certainty not reached in any other way. For this reason, I have included in the first group of the collection herewith submitted, a greater number of one class of wrought instruments, than would otherwise suffice for purposes of examination.

We should naturally expect objects as ancient as these, to be primitive in appearance: if they were not so, the fact would militate, materially, against their claim to be palæolithic. Certain of the marked peculiarities of these quartzes, however, are distinctly referable to specific causes, outside the range of mere antiquity.

In the way of illustration, let us suppose one of two equally developed branches of the human race to have been afforded free access, in glacial time, to the stores of manageable material supplied by the flint-beds of palæolithic Europe, and the other to have been restricted, during the same era, to the deposits of abundant, but intractable quartz, found in central Minnesota. We must believe that, in a case like this, a divergence in methods of work, and consequently in results, would inevitably ensue, and that such effects, perpetuated through the ages, and intensified by reiteration, would finally eventuate in differences of the same nature with those now existing between these roughly wrought quartz remains, and the typical chipped-flint finds of other countries.

It is to be noted that the quartz mineral in question is differentiated from flint, and the coarser sorts of stone, by two important characteristics which, conjoined, could scarcely fail to modify workmanship therein. These are: first, the irregular fracture of this quartz, which causes particular difficulty in working it into ideal forms by the nice operation of chipping: and second, the enduring

angles and points presented by it, when it is either disintegrated by the forces of nature, or reduced to fragments by artificial measures. Many of these natural and semi-natural figures are available, without adaptation, as tools, such as blades, piercers, stone-picks, rasps and hammers: and they have been very generally thus utilized. Quartz implements of this rudest description of all were, no doubt, devoted to coarse work, and were expected to be easily destroyed, and as easily replaced by fresh tools. (For illustration of this point, see Group B, numbers 8 and 9.) Still, most such objects received some few decisive touches directed by human intelligence. It was, commonly, not the working-section of an instrument which required these determining strokes at the hand of man, but rather the base of it, or else that part of the surface which was to be adapted to some sort of handle.

The special type of implement presented in Group A is never included in the rude order here noted, however rough-hewn individual specimens may appear to the casual observer. On the contrary, the implements of this group are wholly artificial forms; they are shaped, usually, with a good degree of comparative skill; and, when broken, the fragments are frequently found preserved, as if to be put to some new use. The quartzes of this series vary somewhat in size, but are seldom much larger than No. 1.

Group A. No. 1. Specimen No. 1 is a typical implement, better wrought than most members of the group. As a first step in the study of this instrument, I beg leave to point out the very slight marks of use left upon its margin at E to E, and also certain corresponding bruises, and traces of pressure, upon the base. The object appears to have been put to but little service, yet it will be observed upon close inspection that the whole of the base bears evidence of applied force, such as might be due to the roughly fitting socket of a handle of horn, or wood.

Such an implement might be operated with no mounting whatever. For a very considerable portion of the glacial year, however, or indeed for an average Minnesota winter of the present presumably warmer period, this would be a thing wholly impracticable, as any person must understand, who has ever attempted to manipulate quartz pieces, even in a warmed apartment, with the thermometer ranging at ten to forty degrees below zero.

Group A. Nos. 2 to 6, and 28 to 31. Implements 2 to 4 illustrate the modification in form and workmanship to which the present type of objects is subject.

No. 2 is a worn implement, thinner than No. 1, one surface of which has been partially cleansed, leaving the other in a nearly natural state. The conchoidal fracture shown at the margin is common to certain of these specimens; as is also the appearance of having had the base involved in some foreign substance.

No. 3 is of a model often occurring among quartzes much smaller than these, and is characterized by the thickness and relative position of the base, and by having one of its surfaces a plane, or nearly such.

No. 4 is a battered implement, not found *in situ*, but picked up about a half-mile south of the notch whence the other pieces of this collection were derived. It was found in a cutting in the river-terrace at this place, recently made through the plane of the quartz yielding stratum, for a wagon-bridge spanning the Mississippi river.

Nos. 5 and 6 are bits of broken implements.

Nos. 28 to 31 are additional specimens which may serve, perhaps, to illustrate the type more fully.

Group B. Nos. 7 to 16. Group B comprises a miscellaneous assortment of quartz objects of various types, brought together with a view to illustrate certain phases of palæolithic handicraft.

No. 7 is presumably a palæolitic weapon. It is one of the best finished pieces of my collection, and is unique, so far as this place is concerned. The dissimilarity of the two sides is not due to incompleteness, nor fracture, as might be conjectured. This is shown by the appearance of that part of the object here labelled as the *back*, which is worn smooth at some points, while at others it is marked with indentations seeming like bruises produced by a hard substance used as a mounting. It was, perhaps, provided with a handle of horn; or it may have been fitted, longitudinally, into the upper section of a wooden club.

No. 8 is one of the very coarse stone-tools to which allusion has been made above. The incurved and broken blade, B to B, is one of many occurring at this place, certain of which are doubtless of natural formation, while others appear to have been shaped by detaching a single curved flake at the required point, as is perhaps the case in the present instance. The evidences of use exhibited by a worn implement are of two sorts; first, abrasion and fracture at the working-section, caused by impingement upon foreign bodies; and second, opposite and corresponding sets of pressure-marks, found at the spot where force has been applied to produce

the impingement. Probably this was done by means of a wooden socket or a like device. The rougher tools appear to have been manipulated, at times, by means of a sort of *half*-socket, as a portion of the base is often deeply bruised, while the remainder shows no abrasion. In objects exhumed directly from the stratum, these markings may be relied upon, as proof of human interference, to an extent which would not be possible, had the pieces indicated been subjected, since deposition, to vicissitudes of climate, or to violent action of either ice or water.

Nos. 8 and 9 are not introduced into the present group for the purpose of illustrating their types, concerning which there is, bye the bye, much to be said; but they are brought forward as examples of natural forms, adapted by palæolithic man to his own service. Such a curved blade, as that of No. 8, would, no doubt, be of utility, in working horn, or branches of wood, or in shaping clubs; while rounded blades, like that of No. 9, might well have been employed in making, or enlarging, cavities in wood. Indeed I have pieces of this kind which, I think, *must* have been so used.

No. 10. Under this head, I comprehend a lot of quartz fragments, which were exhumed from the notch-stratum, while the present notes have been in process of preparation. Having chanced, several days since, upon an extension of this stratum, I took from it, in the course of a few minutes, 72 pieces of waste material. I forward, as No. 10, a considerable quantity of the finer refuse for the double purpose of showing what it is like, and of establishing the fact of the freshness, and freedom from accidental abrasions, of these quartzes.

Nos. 11 and 12. Associated with the bits of No. 10, I discovered Nos. 11 and 12, one of the two being broken at the point, and the other, perhaps, not finished. These little specimens have a likeness to arrow-heads; but whether they are such, or not, is to be determined. It has been believed that no arrow-heads exist at this deposit, since no recognized weapons of the sort have been extracted, hitherto, directly from it. The single quartz arrow-head from Little Falls, exhibited at the Minneapolis meeting of the A. A. A. S., last August, was derived from a source which may, or may not, prove to be a northward extension of the quartz-bearing plane at the notch.

Nos. 13 and 14. Each of these objects represents a large class of finished and unfinished specimens; passing, on the part of the

former, into the type of flattish, and roundish flakes, and, in the case of the latter, merging into a thicker class of implements, somewhat resembling the hatchet in shape.

No. 15 is a small figure, of an unmistakably artificial character, representing a curious series of worked objects, upon whose *raison d'etre* it is too early to pronounce. At the present stage of investigation, they appear unintelligible, except as crude imitations of animals. Average examples of this class of work, when complete, stand upright upon a base, like No. 15, and are relatively well wrought, while bearing upon their surfaces no traces of use, so far as yet observed.

Nos. 16 *a* and 16 *b* are bits of quartz, one of which shows a point or piercer, nearly or quite natural in form. The other is a small blade which has been somewhat fashioned, probably.

Group C. Nos. 17 to 22. Nos. 17 18 and 19 are hammer-stones extracted from the notch-stratum. Specimens 17 and 18 are old and battered examples of their class, while No. 19 is a fresher and nearly typical implement. These rude tools have been coarsely flaked. The worn hammers are adapted to be used, either with the back of the tool held in the palm of the hand, or with the back fitted to a handle. It is possible, however, for these and the like tools to have been employed, first in one of these ways, and then in another, as during the summer, and afterward through the period of cold. This would render practicable two systems of abrasion, evidences of which, not infrequently appear. By holding the back of No. 17 in the right palm, with the wrist toward the base, and with the fingers pressing at the upper points, P P, the instrument will be found in position to effect existing bruises upon its working-surface.

No grooved hammer in the nature of an Indian maul, and no completely grooved object of any kind, has thus far been discovered at this place. Well defined cut-grooves occasionally appear upon one surface of some small implement. Shallow grooves, or rather mere depressions, which are pecked, or gouged, into one side of an implement, are not uncommon, neither are notches, more or less pronounced, wrought in one or both margins of an instrument; as in No. 20, and also in members of Group D. Contrivances of the same nature are further illustrated by Nos. 21 and 22.

Group D. Nos. 23 to 27. No. 23 is a coarse, worn blade of a common kind. The specimen in hand has bruises at its base, and

presents a slightly worn appearance at the margin opposite, thus showing that it has been put to some sort of service.

No. 24 is a round blade of a common type.

No. 25 is one of three or four small quartzes, derived, in part, from the notch-stratum, and, in part, from the same plane, a half-mile, or less, to the north. The specimen here presented is from the notch-stratum.

Nos. 26 and 27 are old and battered tools. No. 27 is unusually small, and is much bruised at the base, and correspondingly broken at the blade opposite. Implements of this sort occur in great variety, as regards form, size, and finish.

Group E. Nos. 32, etc. Nos. 32 and 33 are quartz-bulbs, which, in spite of their rudeness, are neither natural forms, nor the result of artificial fracture, and which from the marking upon their surfaces, and from comparison with other like pieces, I judge to have been inserted, as a head, into some sort of club. The points, P P, of No. 33 were fashioned, no doubt, for the reception of fastenings. The base may, very likely, have rested in a cavity at the top of the club, the bulb of the weapon forming the apex, as in No. 32.

No. 34 is probably an unfinished implement. It has, at one side, a gouged, roundish cavity; a feature which is common to several kinds of implements, and which sometimes occurs under conditions affording clear evidence that the depression in question has not only been artificially produced, but that it has also been subjected to use.

Nos. 35 to 38. I add to this group certain imperfect specimens, as also the quartz piece, No. 38, which seems to have been utilized for rasping purposes.

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SOME CHARACTERISTICS OF THE INDIAN EARTH AND SHELL MOUNDS ON THE ATLANTIC COAST OF FLORIDA. By ANDREW E. DOUGLASS, New York, N. Y.

[ABSTRACT.[1]]

THE Indian earth and shell mounds are distributed very evenly along the Florida coast from the mouth of the St. John's River to

[1] Printed in full in the American Antiquarian for March and May, 1885.

the southern extremity of Lake Worth. The shell mounds are ridges or heaps of great size, planted generally upon the outlying strip separating the lagoon from the sea, and less frequently, upon the west bank of the lagoon. The earth mounds, with rare exceptions, are found on the main-land west of the lagoons. These earth mounds are most probably the work of the same tribes that raised the shell mounds, and living permanently upon the mainland, at stated and limited periods of each year occupied the narrow strip intervening between the lagoon and the sea-beach. The Dupont's shell mound, twenty-five miles south of St. Augustine, beautifully illustrates the progressive growth of one of these heaps, its final decadence and desertion; the portion upon the sea-beach having apparently been completed, while the extremity upon the lagoon is left in the first stage of its occupation. The earth mound, attributed to the same constructors, is found at Rhotan's Landing, on Pellicere's creek, opposite the shell mound. The characteristic feature of this mound is in the existence of three radiating causeways left to facilitate its erection. The same feature is exhibited by a single prominent ridge in the Spruce Creek mound, and in the same way, but still more conspicuously, in the twin mounds in Ross Hamak, on Mosquito lagoon, which are massively built, and show an ovate base area, three hundred feet in length, the greatest width, at the base of the actual mound, being one hundred feet. Other mounds are attached to the terminating slope of natural ridges, to enhance their height when viewed from the plain. Such is Bulow mound, forty miles south of St. Augustine, and Mount Oswald, on the south bank of Tomoka Creek in northeast section of Volusia County. In the vicinity of the latter are extensive shell-ridges, one nearly eight miles in length, and a shell mound about three acres in extent, composed exclusively of the minute shell *Donax;*—this last being unique in this respect. Other earth mounds are found erected on the edge of plateaus or terraces, some feet higher than the plain they face; the soil being excavated on either side and heaped upon the mound, a narrow neck being left still attached to the mound. Such an one is Coco mound, twelve miles north of St. Augustine. The Spruce Creek mound also exhibits special characteristics in an artificial descent to, and landing at the water's edge, as well as in the pits sunk in the vicinity, whence was obtained the earth required in its construction. The Stone House

earth mound, opposite Mosquito Inlet, exhibits a stone casing three feet below the surface, covering the entire mound, and the interior sand is singularly indurated, a condition due to some ingredient in the composition of the soil peculiar to that neighborhood. The two rock mounds on the banks of the Miami river, at Bay Biscayne, are the only instances upon the Atlantic coast of the state, of mounds constructed solely of loose rock. They are possibly so heaped up, to relieve the soil of serious obstacles to cultivation, and may be the work of Spanish, English, or Indian residents. The relics revealed by the earth mounds illustrate the extent and limit of a pre-columbian trade in northern-made stone implements. Such implements are frequently found in such mounds on the coast within the limits of St. John's county, but they are not found farther south. They could hardly have been abundant as no mention is made of them by French or Spanish historians of the early historic period. It is a question, whether such objects found in the earth mounds were *intentionally deposited* with the burials, buried there for *concealment*, or *accidentally dropped* and lost while the mounds were being constructed.

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THE SACRIFICIAL STONE OF SAN JUAN TEOTIHUACAN. By AMOS W. BUTLER, of Brookville, Ind.

[ABSTRACT.]

FROM the best information attainable I can learn of no place where the Sacrificial Stone of San Juan Teotihuacan has been described.

This stone is but a few yards from where the so-called "Path of the Dead" enters the open court south of the Pyramid of the Moon. It is just west of a mound about eighteen feet high, beneath which is an opening extending some distance into the ground. The stone rests on its base leaning against a pile of debris, which prevents any view of its bottom and one side. This stone is of gray granite weighing about twelve tons. It is cut from one piece of stone and is evidently a combination of sacrificial stone and idol. The cutting of this stone is well executed, but does not equal that of the great sacrificial stone taken from

beneath the "Great Plaza" in the City of Mexico. The difference in carving may, most likely, be explained by a difference in the time of their manufacture; that of San Juan Teotihuacan being, perhaps, much the older.

The stone at San Juan is five feet six inches square at the top and bottom, and exactly six feet high. Three sides and the top are exposed to view. The top is dressed very true and is unmarked, save by a gutter two and one-half inches wide running through its center to the front and rear, down the former of which it may be traced for a short distance, expanding as it becomes less distinct. Around the top is a square groove two inches deep; about half way down the cap is a semicircular groove less than one inch deep extending entirely around the stone.

Below the cap the sides of the stone abruptly become smaller. This smaller part at the front of the stone is occupied by the figure of a gigantic human head, artistically arranged to support the upper part of the stone. The nose is very large expanding toward the end, where are cut two small holes for nostrils. The eyes are cut into the rock and are surrounded by grooves representing either lids or eyebrows. The mouth is cut into the stone about an inch, and is similar in shape to the eyes. It is also surrounded by a groove to represent the lips. Upon each side of the head is a slightly oblong cutting, with a smaller raised circle upon each; these are the ears of the figure. From each ear a ridge of the same size extends to the posterior surface of the stone. Immediately below each ear and attached thereto is an oblong figure which I have considered an ear pendant. Just below the ears the stone gradually expands to a base the same size of the cap. This slope may have been intended for shoulders. The sides of the face are cut almost straight, but the lower portions, approaching the chin, are rounded. The chin is square at the end. The neck is covered by a necklace which is divided into three parts by slightly curved parallel lines running nearly horizontally; these are cut by lateral lines, part of them running at right angles dividing the necklace iuto angular blocks, most probably representing beads or precious stones. Below the chin in the body of the image, is a rectangular cavity eight inches long, three inches wide and three inches deep, into which perhaps a breast-plate was fastened. Extending in a straight line from two sides of this opening are two raised parallel cuttings. Within sixteen inches of

each side they turn angularly toward the lower corners; before reaching the corners they again turn parallel to their first course meeting the sides of the stone about two inches above the base. Between the large cavity just mentioned, and the base of the stone are two peculiar scroll-like figures, each divided into four parts which meet each other in the centre of the block, in the form of an inverted V.

The only place I can find any reference that probably refers to the stone I have described is in Mr. Fred. A. Ober's new book entitled "Travels in Mexico." He says: "No vestige of image or statue remains save a great carved block called a sacrificial stone, now lying two hundred yards from the 'Pyramid of the Moon.'" This may refer to the stone I have described.

The early Spanish historians tell us these pyramids were occupied by temples, and by idols "upon whose breasts were plates of gold and silver." When the Spaniards occupied this famous valley the superstitious and destructive Bishop Zumarraga, destroyed these, together with all other evidences of the early worship of the inhabitants upon which he could lay his hands.

Were these idols destroyed?

Such masses of rock as these ancient Mexicans used could scarcely have been broken by any means the Spaniards could employ. I think it more probable that the temples were destroyed and the idols overthrown, the latter becoming covered by debris, or buried by Cortes' band for fear the natives, whom they wished to christianize, finding them should return to their idolatrous worship.

The sacrificial stone I have described was excavated, near where it now lies, by the order of Maximillian, but he, by reason of his death, was prevented from removing it to the Capital.

I think it very probable that this stone was upon the top of one of these Pyramids. Owing to its proximity to the "House of the Moon" it is more probable that it at one time occupied the summit of this monument.

Considerable research fails to show more than one figure in any way similar to that upon this stone and that is the so-called statue of Quetzalcohuatl from Cholula. Can it be that these two figures represent the same person—the great "God of the air" of the ancient Toltecs?

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## Disputed points concerning Iroquois pronouns. By Mrs. Erminnie A. Smith, Jersey City, N. Y.

[ABSTRACT.]

The use of pronouns and their relations to one another may be considered as the greatest difficulties which the student of the Iroquois language has to encounter.

The peculiarity of different words requiring unlike pronouns for the same person and number, and the number of these arbitrarily used pronouns have undoubtedly led most pioneers in Indian languages into incorrect conclusions.

One cause of confusion, we venture to say, was the early division of these dialects into two genders only, thus proscribing the neuter form with its pronoun *it*, and introducing the indeterminate *on* of the French. On the contary, instead of the two genders "noble and ignoble", we find in these dialects the masculine, the feminine and the neuter, or neither, genders. The simple proclitic pronouns of the 3rd person, are the only words that specify the gender of the objects to which they refer. The simple 3rd person masculine, *he*, has one pronoun which is always incorporated. It is *ra*, which in some of the Iroquois dialects is aspirated into hă. The r sound is simply a trill of the tongue. The ră is nearly equivalent to r-r-h-ă which fully aspirated is hă. The simple 3rd person feminine, *she*, has three, yăk, K, ye or yă, these are also always incorporated. The simple 3rd person neuter has three, yŏk or yu, wă and kă which are also always incorporated. The indeterminate or indefinite pronoun is expressed separately, is indeclinable, only taking a plural ending, and is never compounded with verbs or their equivalents. Să-kă'-nă is the Tuscarora, some one, somebody, while oñ'-kă is the Mohawk word some one, somebody. This pronoun in the singular when followed by its verb without an incorporated objective pronoun, expresses its gender through the verb's incorporated nominative; as, some one works, is some one he, or she, works, thus: să-kă'-nă rhu'-yu'-nä, some one he works, or să-kă'-nă kă-yu'-nä, some one she works. Of animals and things, in speaking, one uses stă-ă-wûñ'-tă, something, as: stă-ă-wûñ'-tă yu-yu-nă, something, it works; or in Mohawk, something causes cold, makes it cold, becomes something it makes cold; thus: nă-hŏ'-tă wăt-ho'-răte, something it makes cold, oñ'-kă ră-noñ'-wes, some one he loves; oñ'-kă ye-noñ'-

wes, some one she loves; nă-hŏ-tä kă-noñ′-wes, something it loves; or oñ′-kăh′ răt-kăh′-tos, someone, he looks; oñ′-kă yoñt-kăh-tos, nă-hŏ′-tä wăt-kăh′-tos, something it looks.

This is the only method of expressing in these dialects the indeterminate *on* of the French, in words which have no object pronoun. In these words we are obliged, by the very nature of the Iroquois pronouns, to express determinately the gender of the "some one" or "something;" but in words with infixed object pronouns, when the 3rd mas. he is the subject, and the 3rd mas. him is the object, or when the 3rd mas. he is the subject and the 3rd fem. her is the object, or when the 3rd fem. she is the subject and the 3rd mas. him is the object, or when the 3rd fem. she the subject and the 3rd fem. her is the object, or when either of the sing. 3rd personal pronouns, he or she, is the subject and the sing. 2nd person, thee, is the object, there can be no gender or sex expressed. However these genderless pronouns, representing the foregoing relations, correspond in no way with the subject pronoun *on* of the French. We cannot here introduce the table of relations proving the above, but would inquire why in the accompanying table of the simple conjugation, the pronouns of the singular 1st and 2nd persons are given in the same form as are afterward given by these authors to indicate the relation beween the 1st and 2nd subject and the 3rd object pronouns, as in the place of k-noñ′-wes, I love, and s-noñ′-wes, thou lovest, they have ke-noñ-wes, I love one, and se-noñ′-wes, thou lovest one. Upon pages 21 and 130 Pére Marcoux's Grammar we find the following: *on* is the 3rd person indefinite, and is found in all verbs and all time. And in the conjugations the feminine *elle*, or she, is applied to all things which in English require the pronoun it, and the indeterminate *on* is made to serve under exceptions (for to his *principies fixes*, Pére Marcoux is ever consistent) for what, I feel convinced, is the feminine: therefore I conclude that his feminine pronouns are in fact the neuter and his indeterminate the real feminine pronouns which, I trust, will appear. Upon page 81, "Essential remarks upon the usage of verbs," we find "the 3rd indefinite should be used in place of the 3rd feminine, out of respect and politeness when alluding to women." Thus by exception he would allow us to use what, according to our table, is in reality the feminine. Under this note we find the following examples: ke′-kä nis′-tĕñ-hă, I see one my mother, for k-kä′ nis′-

tĕñ-hă, I see it, my mother; ye'-te-roñ, one abides, is at home, for kĕñ'-te-roñ, it is at home, abides; te-să-kŏ-snie ne-ro-sot'-hă, he attends to one, his grandmother, for te-hăs'-nie nĕrŏ-sot'-hă, he attends to it, his grandmother; yă-kă-wĕñ-he'-yoñ, one is dead, for yă-wĕñ-he'-yoñ, it is dead. In these examples he enforces the use of his indeterminate pronoun, which is our feminine, in the place of his feminine which is our it, and in reality brings all womankind under their own pronouns, thus separating them from the surrounding of beasts, male and female, demons and things, with which he first environs them.

To what an emergency Père Marcoux was reduced to uphold consistently his division of gender, appears in the appended list of idioms, in which one reads (page 132), "It has been said in the first part that men alone were of the noble gender, and that the feminine gender belonged to women, animals, demons, etc.; it is for this reason that ră'-tcin (he is male) must be feminized when speaking of animals. Therefore one says, kă'-tcin, she is male. It is unnecessary to say that the translation which our classification of gender would allow for the latter, rendering the kă'-tcin (it is male) is the correct one. Again, upon page 56, under impersonal verbs, Père Marcoux remarks that these verbs have but one person to each time and that this is always "the 3rd person feminine." For instance where in the French one would say "il pleut," which in English must be translated it rains, not recognizing an it, he gives his feminine, which appears on our table as the neuter. For example: yo-kä no'-res, it rains, wă-kĕ'-rhäs, it snows, yo-kä-no-roñ, it rained, yo-ke-ră-hoñ, it snowed, eñ-yo-kä-no-re it will rain, ĕñ-wă-kĕ-rä nĕ, it will snow, etc.,etc. All of which examples are not impersonal verbs, as their conjugations, in all persons and numbers, moods and tenses, are given fully in our accompanying table.

Upon page 69 he continues further; the personal verbs may be used impersonally as, io-iă'nere, it is good, from wa-kia'-ne-re, I am good; io-te-re-wis'-on, it is a finished matter, from wa-ka-te-ri-wi-soñ, I finished my business, made a contract; ioñ-we-señ, it is pleasant, etc., from wă-koñ-we'-sen, I am pleasant, agreeable; io-tsă'-nit, it is terrible, from wă'-ke'-tsă-nit, I am terrible, etc.

The necessity which Père Marcoux here finds for impersonalizing all verbs in order to give to the pronoun he has denominated she, its proper sense, in a manner divides gender into the three

divisions which we have claimed for it. Furthermore, by thus impersonalizing all verbs, causing the feminine pronoun, she, to represent always the English it, and the indeterminate "on", to stand, by exception, for the she, we find ourselves really occupying the same ground; Pére Marcoux's arrangement suiting better the understanding of the French student and the other certainly simplifying the language to the English mind.

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LOCAL WEATHER LORE. By AMOS W. BUTLER, of Brookville, Ind.

[ABSTRACT.]

WEATHER lore is peculiar to no particular people. No nation exists but what has some popular beliefs regarding weather signs. The ideas involved are as old as written history.

In Great Britain several works have been published on the subject of popular weather sayings, but in this country, with the exception of the little volume of "Weather Proverbs" by Lieut. Dunwoody, published by the Signal Service, I know of no publication.

Many curious sayings have been transported from Germany and Great Britain and have found a lodgment in America. Some of these still retain their original form and meaning. There are others, however, which we can not appreciate, owing to the fact that the idea is misapplied.

The advent of rapid and easy communication marks an epoch in the social life of the human race. We are upon the borders of two periods. The shadows of the superstitions of our fathers hang round about us as we are entering the period enlightened by scientific meteorology. The rapid increase in the knowledge of meteorology, together with sufficient means for its distribution, has materially changed many ideas in regard to the causes and forecasts of weather. With the age that is now passing away will be lost many of the quaint and curious sayings of the olden time. It behooves us, therefore, to apply ourselves that this much of the social history of our ancestors be not permitted to pass away with them. What would we not give had we an account of the folk lore of the different European nations for the last two centuries, to say nothing of

the period before that? A half century hence much, which may now be preserved with little effort, will have gone forever. No doubt there are many proverbs which have become obsolete, and perhaps many more are rapidly approaching extinction.

The weather, no doubt, attracted the attention of men from the beginning of time. By continued watching, certain real or fanciful relations between weather changes and various objects have been noted and arranged into popular form.

These proverbs form the basis of a peculiar system of meteorology which is now passing away.

Certain ideas in somewhat similar forms appear to be world-wide. By far the greater number of proverbs, however, are of a local character, having only a local significance.

The study of "Weather Lore" is of twofold importance: first, its relation to established meteorological laws; second, its value considered from a sociological standpoint.

It is not the province of this paper to discuss the truth of any of these proverbs, but many of them will be found to be based upon principles which the most recent meteorological investigations have demonstrated to be true.

The proverbs of general distribution have been treated before. I shall therefore confine my attention to certain prognostics which I have collected from southeastern Indiana, most of which, I believe, have never been printed.

I have omitted entirely from this paper all proverbs I have found in Lieut. Dunwoody's article, but I have introduced some of the ideas he has mentioned in different language from that in which they are presented by him.

The two branches of the White Water River meet at Brookville, forming an acute angle. One comes from the north and the other from the northwest; after uniting, the river pursues a slightly southeastern course. The valleys are bordered by high hills, the greater portion of which are heavily wooded.

The warm southern currents are those which generally bring rain. From this fact we can easily understand the meaning of the following proverbs which are commonly used in the locality just mentioned: "When smoke goes up the stream it will soon rain;" or, on foggy mornings, is frequently heard; "When the fog goes up the river it will soon rain."

From these examples we can perceive the fact that even the

most circumscribed areas have their effect in the production of weather proverbs.

A glance over some of the proverbs I have collected reveals many which are common in certain Southern States. Upon examination I find that the south half of Indiana was largely settled by people from the Southern States, as far north as upper Maryland and west into Kentucky, the greater portion of them coming from Maryland, Virginia, Kentucky and North Carolina. Mingled with the remaining proverbs of the old Southern stock I find many prognostics which suggest a Teutonic origin. Further investigation reveals the fact that in later years a wave of German emigration has swept over this part of the State and has left its impress upon the "Weather Lore" of this region.

Many proverbs are believed with religious devotion. This is especially true among the Germans. With the later generations of the English speaking people most of the proverbs of their ancestors are not only disbelieved, but many of them are forgotten.

To afford comparisons with the prognostics prevalent in other localities I have appended a list of the local sayings in regard to the weather:

Relating to the moon—"Circle round the moon, it will rain soon; circle round the sun, it will rain none." "When there is a halo 'round the moon, the number of stars visible within the circle indicate the number of days before it will rain."

Referring to fog and smoke are the two proverbs I have before mentioned — "When the fog goes up the river it will soon rain," and "When smoke goes up the stream it will soon rain."

Prognostics regarding clouds — "Cirrus clouds are known as rain seed, and indicate an approaching storm."

Regarding frost—"Three black frosts (in autumn) are followed by rain."

Regarding snow—"When snow comes from the east or northeast, it indicates a deep snow." "Snow will remain on the ground a week for each day it remains on the limbs of the trees."

Proverbs relating to rain — "Red in the evening a sign of fair weather; red in the morning a sign of foul weather." A popular saying, which I am informed was much used in olden times at country parties when it was raining, is as follows: "More rain, more rest, kiss the girl you love the best." "More rain makes the grass grow."

Relating to lightning — "Lightning in the south indicates dry

weather." "Lightning in the northwest indicates rain within twelve hours."

Relating to wind — "When there is no wind it indicates foul weather."

Many proverbs are mentioned as referring to different animals. I give some of them: "When hogs and cattle manifest uneasiness, are restless, and are apparently seeking shelter, a change of weather is near." "A thick coat on fur-bearing animals indicates a long cold winter." "A well lined and well filled squirrel's nest indicates a severe winter." An old trapper has given me a few proverbs that were formerly in vogue when many of our now extinct animals were still found: "When beavers are very industrious, collecting their food early in autumn, it indicates a long, cold winter." "Deer are very playful before rain." "Foxes and wolves congregate and howl before a change of weather." "The otter, before a cold winter, lays up a large supply of food." Other proverbs taken from those collected relating to animals are as follows: "When hogs gather up sticks and carry them about, expect cold weather." "Moles may be seen digging their passages industriously in all directions before rain."

Proverbs relating to birds — "Crows seen in winter indicate an early spring." "When snow-birds fly low, under the bushes, appear restless, and when they alight and erect their wings, it indicates cold weather; but when they frequent the top of bushes, are quiet, and do not appear to be seeking covert, expect fair weather." "Ruffed grouse drum more frequently before rain." "When turkey vultures are seen in winter it indicates warm weather soon."

Prognostics concerning insects—"When lightning-bugs appear in great numbers it indicates rain." "When flies congregate in the house expect rain soon."

Concerning trees — "When sycamore trees are very white in autumn expect a cold winter."

Concerning days—"If it rains on Easter it will rain for the next five Sundays." "No rain on Easter, no good oats crop." "A succession of warm days, followed by wind, will bring falling weather." "A white Christmas makes a green Easter."

Proverbs relating to months — "The first three days of March rule March, April and May." "A dry June never made a dear bushel of corn."

General prognostics — "When a pitcher of water sweats it will

soon rain." "When a cellar becomes damp in summer expect rain." "Human hair curls before rain." "Artificial hair will not remain curled in wet weather." "When plastering or masonry is hard to dry, mechanics say it indicates rain."

I have now presented to you the greater part of the local prognostics I have collected. Some of the members of this association may wonder why such a paper should be presented. Many of us, I think, enjoy such papers because they are of a popular character; besides, they treat of a long neglected branch of sociological study.

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THE SACRED PIPES OF FRIENDSHIP. By FRANCIS LAFLESCHE, Indian Bureau, Interior Dept., Washington, D. C.

[ABSTRACT.[1]]

THE Omahas have two sacred pipes which belong to the entire tribe and are in charge of the sub-gens called the "Ne-ne-ba-tan" of the In-kae-ra-bae gens. According to tradition, one set of pipes was given to the whole tribe in common, and one pipe to each gens of the tribe who appoint one of its sub-gens called "Ne-ne-ba-tan" to take charge of the same. To the different gens of the tribe were also given tobacco pouches made of various animals and bird skins. Rituals are connected with each of these sacred pipes.

The "Ne-ne-ba Wea-ah-wan," or the pipes to sing with, are commonly spoken of by the Omahas as a branch of the sacred peace pipes of the whole tribe, and are used to form ties which are considered more sacred than the natural ties of relationship. "Father," "Son," are the only terms used to denominate the tie formed by these pipes.

A man who has been initiated and taught the ritual can "tie the friendship pipes." Each article used and each ornament fastened to the stem has a significance and meaning which is stated in the ritual and which must be recited in low tones by the maker, so that no one may overhear, as he prepares and ties each article on. The following articles are used:—

[1] This paper will be given in full in the Report of the Peabody Museum of American Archæology and Ethnology, Cambridge, Mass.

Ash for the stem, red and green paint, tanned skin, two kinds of eagle feathers, owl feathers, head of the woodpecker, duck bill with the skin of head, neck and breast attached, and hair of the rabbit.

When the wood is seasoned and the pith removed, the length of the pipe stems is measured off by seven stretches of the thumb and forefinger, this being the measure for sacred pipes. The pipes are next painted in solid green. Green is used to signify the clear blue sky when there is not a cloud to mar its beauty and peace. When the green paint on the stem is dry a straight groove is cut the length of the pipes and painted red. This groove is shown the youngest child of the man who is made "son" by the receiving of the pipes. The ritual of the pipes is given to the man made "son" through the innocent child who is too young to remember the sacred words and therefore selected so that the ritual may not pass beyond the father of the child. All the other articles are placed upon the pipes symbolically and in accordance with the ritual.

Two gourd rattles belong to these pipes and are used with them in singing the songs of the ceremony. A wild-cat skin and a crotched stick serve as a nest and resting place for the pipes. The crotched stick is painted red for the same meaning as the streamers. A sacred ear of corn also belongs to the pipes and is painted at one end in the same manner as the gourds and tied to sticks painted red having a downy feather at one end. The corn is used to bless each child who brings the gift made by its parents to the pipes. No levity is allowed while the pipes are taken up and the songs are being sung. The gracefulness and the solemnity of the ceremonies can hardly be described.

When the pipes are at ceremonial rest the bearers take their seats behind the pipes within easy reach, and never leave them unless it is absolutely necessary during the ceremonies which last four days and nights. No one is permitted to go between the pipes and the fire except for the purpose of making presents to them.

On the fourth morning the youngest child of the man to whom the pipes have been brought is carried to the lodge in which the ceremonies connected with the pipes have been performed. The party bringing the pipes go after the child with songs and ceremonies appropriate to the occasion. A song is sung when

standing at the entrance of the door of the lodge when starting for the "hun-ga," as the child is called. "Hun-ga" means the leader, or the ancient one. The child is brought with ceremony on account of its innocence and gentleness, which is representative of peace and docility.

The goods brought by the "wa-wan" party for distribution to those who gave horses are called "hun-ga-wa-in," hun-ga blankets, and one is given to every man who made a gift to the pipes. It is the custom to give these to the poor of the tribe if the receiver desires to count the number of presents he made to the pipes. A man must count a certain number of presents that he has made to the pipes before he can be numbered among the braves of the tribe and have the privilege of tattooing the sign on his daughter's forehead, which is a round blue spot representing the sun.

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OBSERVATIONS UPON THE USAGE, SYMBOLISM AND INFLUENCE OF THE SACRED PIPES OF FELLOWSHIP AMONG THE OMAHAS. By Miss ALICE C. FLETCHER, Peabody Museum, Cambridge, Mass.

[ABSTRACT.[1]]

THE Omaha tribe of Indians is divided into ten gentes. Each gens is composed of several bands or sub-gens. The order of the gentes is as follows:

Those upon the north half of the circle, or the In-sta-sun-da side, beginning at the east, are:

In-sta-sun-da.
In-grae-ze-dae.
Ta-pa.
Tae-sin-dae.
Ma-thin-ka-ga-hae.

Those upon the south half of the circle or the Hun-ga-chey-nu side, beginning at the east, are:

Wae-zin-stae.
In-kae-sab-ba.
Hun-ga.
Tha-ta-da.
Kan-sae.

[1] The paper will be given in full in the Report of the Peabody Museum of American Archæology and Ethnology, Cambridge.

According to one tradition seven pipes were distributed among seven sub-gentes of the following gentes: In-kae-sab-ba, Tha-ta-da, Kan-sae, Ma-thin-ka-ga-hae, Tae-sin-dae, Ta-pa, In-sta-sun-da. Another tradition says, that seven sacred taboo articles were given to these same sub-gentes as the equivalents of pipes. And still another states that seven old men brought the sacred pipes and passed around the tribal circle, distributing sacred articles and assigning duties connected with them.

At the present time only the two tribal pipes in charge of the "Ne-ne-ba-tan" sub-gens of the In-kae-sab-ba are known. The pipes said to belong to the previously named gentes are spoken of as existing, but it seems probable that they are symbolic or potential, rather than actual. The sacred pipes of war are distinct from the tribal pipes already mentioned.

The "Ne-ne-ba-wea-wan" or the sacred pipes of fellowship are spoken of as the branch of the tribal pipes. The inference from this term would be that the former pipes were secondary in their character, whereas there is evidence that they are of a general character, and that as between the two, the tribal pipes are the special ones.

The symbols used in these pipes are such as to appeal strongly to the Indian mind and religious belief. The Omahas have two sacred trees, the ash and the cedar. The ash is connected with the beneficent natural powers. The cedar is linked with the destructive agencies, thunder, lightning, wars.

Seven spans is the length of a sacred pipe. Tradition gives seven sacred pipes to the tribes, or seven sacred articles, the equivalent of the pipe, or, seven old men bestow the pipes; in every tradition the pipes are meted out by seven.

Seven is repeated four times in the symbolical arrangements of the pipes. There are seven ceremonial movements or positions of the pipes. The ceremonies connected with the pipes are divided into seven parts. Seven articles are needed and used for the ceremonies. Seven is regarded as related to astronomical worship, and many of the articles used on the pipes seem to be allied to such religious ideas. The ritual gives similar reference. The ritual is secret. Comparatively few Indians have been able to obtain it, as a strong endorsement of the man's character is necessary, and he is also required to make large gifts, in order to secure a knowledge of the ritual. To old and young, however,

the symbolism of the pipes is more or less apparent; myths, sacred personal names, objects of taboo and gentile distinctions are connected with the different articles that appear on the pipes. These various emblems are interwoven in the thoughts of the people, their ceremonials, traditions and stories; their personal experience, their dreams, and in fact everything which links their lives with the seen and unseen.

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## TITLES OF OTHER PAPERS READ IN SECTION H.

THE THREE CULTURE PERIODS. By Prof. J. W. POWELL, Director of the Bureau of Ethnology, Smithsonian Institution, Washington, D. C.

MYTHOLOGY OF THE WINTUNS. By Prof. J. W. POWELL, Director of the Bureau of Ethnology, Smithsonian Institution, Washington, D. C.

SOME PARALLELISM IN THE EVOLUTION OF RACES IN THE OLD AND NEW WORLD. By Dr. DANIEL WILSON, President University College, Toronto, Canada.

REMARKS ON NORTH AMERICAN RACES AND CIVILIZATION. By EDWARD B. TYLOR, F. R. S. Oxford, England.

FORMATION OF IROQUOIS WORDS. By Mrs. ERMINNIE A. SMITH, Jersey City, N. J.

ETYMOLOGY OF THE IROQUOIS WORD RHA-WEN-NI-YU. By Mrs. ERMINNIE A. SMITH, Jersey City, N. J.

OMAHA CHILD LIFE.[1] By Miss ALICE C. FLETCHER, Peabody Museum, Cambridge, Mass.

ARCHÆOLOGICAL EXPLORATIONS BY THE PEABODY MUSEUM OF AMERICAN ARCHÆOLOGY AND ETHNOLOGY,[1] COMMUNICATED BY REQUEST OF THE TRUSTEES OF THE MUSEUM. By F. W. PUTNAM, Curator Peabody Museum, Cambridge, Mass.

DESCRIPTION OF THE HUMAN REMAINS FOUND IN THE "INTRUSIVE PIT" IN THE LARGE MOUND OF THE TURNER GROUP, LITTLE

[1]These papers will be published in the Reports of the Peabody Museum.

MIAMI VALLEY, OHIO, DURING THE EXPLORATIONS OF MESSRS. PUTNAM AND METZ.[2] By Miss C. A. STUDLEY, Assistant in the Peabody Museum, Cambridge, Mass.

THE MANNER IN WHICH INDIANS MADE THEIR STONE IMPLEMENTS. By P. R. HOY, M. D., Racine, Wis.

THE IMPORTANCE OF THE STUDY OF PRIMITIVE ARCHITECTURE TO AN UNDERSTANDING OF THE PREHISTORIC AGE IN AMERICA.[3] By Rev. S. D. PEET, Clinton, Wis.

USES OF THE EMBLEMATIC MOUNDS.[3] By Rev. S. D. PEET, Clinton, Wis.

TRIBAL AND CLAN LINES RECOGNIZED AMONG THE EMBLEMATIC MOUNDS.[3] By Rev. S. D. PEET, Clinton, Wis.

EVOLUTION OF ANIMAL LIFE ILLUSTRATED BY A STUDY OF THE EMBLEMATIC MOUNDS.[3] By Rev. S. D. PEET, Clinton, Wis.

THE DIFFERENT RACES WHO BUILT MOUNDS IN WISCONSIN.[3] By Rev. S. D. PEET, Clinton, Wis.

A SEARCH IN BRITISH NORTH AMERICA FOR LOST COLONIES OF NORTHMEN AND PORTUGUESE. By R. G. HALIBURTON, Q. C., Ottawa, Canada.

UPON THE EVOLUTION OF A RACE OF DEAF-MUTES, IN AMERICA.[4] By Dr. A. GRAHAM BELL, Washington, D. C.

[2] This paper will be published in the Reports of the Peabody Museum.
[3] These papers will be published in the American Antiquarian.
[4] Published in full in the Memoirs of the National Academy of Sciences, 1885.

# SECTION I.

# ECONOMIC SCIENCE AND STATISTICS.

# ADDRESS

BY

## GENERAL JOHN EATON,

VICE PRESIDENT, SECTION I. ECONOMIC SCIENCE AND STATISTICS.

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## *SCIENTIFIC METHODS AND SCIENTIFIC KNOWLEDGE IN COMMON AFFAIRS.*[1]

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THE speaker, after calling attention to the name of the section as expressive of its purpose and functions, spoke of the apparent neglect of the thoughts and interests of ordinary life by scientists. Science, it is true, has had to struggle for existence and has had to choose the most defensible positions for its early work, but the time has now come, at least in this practical land, when it must interest itself in every-day topics. The methods of mathematical science may explain statical and dynamical sociology as well as statical and dynamical physics. Of course the consideration of such topics must be conducted with a constant recognition of the freedom of individual will and action as well as of the substantial regularity of cause and effect as shown among great numbers of people over long periods of time. Science has already destroyed augury by the flight of birds, and will hereafter put an end to notions equally baseless, though still potent in the most common translations of commerce and agriculture. He would need to be better at cataloguing than Homer was, who should attempt to name the myriad groundless notions that today regulate or effect the conduct of personal or public affairs in these days of scientific triumph.

After mentioning some of the effects sure to result from the entrance of science into common life, the speaker further and more minutely instanced the effect of the production and use of measures and weights, both of the progress of practical science itself and on the comfort and security of man, as an example of the way

[1] Abstract of address by the Secretary of the Section.

in which scientists might aid humanity in many directions. But the desire for "original research" has filled most scientific minds to the exclusion of "useful adaptation." Is science for man, or man for science? and is there any good in science which is not measured by its benefit to mankind? How much patience is shown in observing the habits of a mosquito, and how little when asked to tell the world about it in a useful way. Do not some scientists believe that the dissemination of scientific truths is beneath their dignity? Do not some of them believe or behave as if they believed that truth is not really truth till garbed in their terminology? We all know collegians who would not relish their triennial catalogue unless printed in the customary bad Latin. All such foolish notions ill befit science if it is to become the handmaid of man in daily life.

The teaching of scientific truth is as respectable as its discovery, and will become yet more deserving of respect when a truly scientific way of teaching becomes more general; for, contrary to common opinion, the scientific method of instruction is more rare and less understood than the scientific method of research.

This scientific teaching method knows that early life is the shaping period of all men's existence, and for most, the chief time for acquiring knowledge; hence the law of simplicity and lucidity in using words and the law of presenting things concretely instead of abstractly, are fundamental rules in its code, leaving scientists at perfect liberty to use other kinds of words and methods whenever deemed necessary for the exact expression or sure preservation of scientific truth.

This scientific method of teaching is now needed to preserve the classical branches from impending disuse. If adapted and applied everywhere in scholastic instruction, it would speedily, and very greatly increase the number of people interested in the higher and abstruser parts of intellectual effort, scientific as well as literary and classical, theoretical as well as practical.

This scientific method of instruction, if properly understood, would demonstrate its own economy, and in its light the general instruction of the whole community becomes a condition precedent to the promotion of science, and its data are fit subjects for our discussion here.

The men who wish to make science practical, also wish to make

it familiar to all; every agency for its effective and rapid dissemination is welcomed be it periodical, museum, or treatise. It is only by substitution that we can get rid of low and vile books; the useful and the beautiful variously prepared for varying tastes and capacities, will gradually introduce scientific fact and moral truth into every mind which needs either for its full development or further employment.

What shall these books be? An all important question: certainly they must contain whatever of value science, art and morals have found.

To this formulation of useful knowledge for the daily use of man, everything is pointing. Every invention tends to centralize the thought and action of the world to this end. The time is approaching when every science will exist as a whole, while yet relating itself to every art and yielding its practical lessons for the use of every man; the influence of this condition will begin with birth itself.

The speaker then enlarged somewhat on the province of the census and other publications of the government, federal, state, and local; favoring the idea of making local publications appear at short intervals of time, and contain minute details, while the decennial census should be of vastly wider scope than is usual in such publications.

The local publications could easily be made to contain items intended for summary by intermediate instrumentalities of government, and these in like manner might provide for summaries by the state and finally the nation.

As an instance of voluntary coöperation as an effective agency in the collection of information for the public use, the speaker mentioned the annual report of his own office, the National Bureau of Education. Were such publications common in other branches of public life and interest, each nation might distil them into a volume for the use of all others, and thus a solid foundation for internationalism of a truly noble and scientific kind might be laid.

# PAPERS READ.

## Commercial relations of the United States with Spain and her colonies. By His Excellency Don Arturo de Marcoartu, Madrid, Spain.

[ABSTRACT.]

On many occasions the development of the commerce between the United States and the Spanish Antilles has been recommended, but this is the first time, I believe, that the improvement of the relations of all Spain, I mean of the Spanish Peninsula and her colonies, with the United States has been discussed in public.

At this very moment the American and Spanish governments are negotiating, in Madrid, a treaty of commerce between this country and Cuba and Porto Rico. No doubt such a treaty can increase the wealth and the enjoyment of the commodities of both countries, but North America and Spain, the most southwestern state in Europe, have adequate products to exchange and want to supply each other.

The following statements give an idea of the imports and exports of the United States and Spain and her colonies in America (Cuba and Porto Rico), in Africa and in the Pacific (Philippine Islands).

IMPORTS INTO THE UNITED STATES.

| | 1880. | 1881. | 1883. |
|---|---|---|---|
| Spain, | $ 5,786,664 | $ 6,283,342 | |
| Cuba, | 65,743,164 | 62,281,246 | $65,544,534 |
| Porto Rico, | 4,288,136 | 4,614,391 | 5,477,493 |
| Spanish Possessions in Africa, | 180,585 | 288,794 | |
| All other Spanish Possessions, | 8,569,579 | 8,926,419 | |
| Total imports from Spain and her colonies, | 84,568,138 | 82,394,192 | |
| Total imports into the United States, | $696,807,175 | $670,209,693 | |

The principal imports into the United States from Cuba are sugar, molasses, tobacco, and manufactures of this article. The principal imports of Porto Rico are sugar, molasses and coffee.

EXPORTS FROM THE UNITED STATES.

| | 1880. | 1881. | 1883. |
|---|---|---|---|
| Spain, | $ 14,141,375 | $ 13.683.684 | |
| Cuba, | 11,322,370 | 10.963,464 | $15,103,703 |
| Porto Rico, | 1,898,830 | 1,800,464 | 2,164,766 |
| Spanish Possessions in Africa, | 219,641 | 218,261 | |
| All other Spanish Possessions, | 1,551 | | |
| Total exports to Spain and her colonies, | 27,578,767 | 26,753,342 | |
| Total exports of the United States, | $889,683,423 | $833,547,597 | |

THE TOTAL EXPORTS AND IMPORTS OF SPAIN AND HER COLONIES ARE AS FOLLOWS:

| | 1880. | 1881. |
|---|---|---|
| Imports, | $84,568,138 | $82,394,192 |
| Exports, | 27,578,767 | 26,753,342 |
| | $112,146,905 | $109,147,534 |

THE TOTAL IMPORTS AND EXPORTS OF THE UNITED STATES ARE:

| | |
|---|---|
| 1880 | $1,586,490,598 |
| 1881 | 1,503,757,290 |

The principal exports from the United States to the Spanish Antilles are living animals, bread, breadstuffs, coal, some cotton manufactures, drugs, acids and mineral oils.

The total commerce of 25,000,000 of inhabitants in Spain and her colonies with the 50,000,000 in the United States, is only 110,000,000 of dollars made by 75,000,000 of people, or making yearly 1.4 dollar per head; a very insignificant figure, considering the advantageous conditions given by nature to the American Union and Cuba, in their proximity and the difference of products to be exchanged.

An examination of the suffering condition of the trade between America and Spain shows:

1. That the letters for Spain from Boston, New York, Philadelphia, Baltimore, in fact, from all the states of the American Union, generally go to northern latitude (Liverpool), and come down to southern latitude in the Iberian Peninsula, about the same latitude as that of the principal American cities; that is to

say, that letters between Spain and North America are uselessly made to take twice the time and to go double the distance that they should.

2. Cablegrams between New York and the Iberian peninsula go by to the northward of that territory, and therefore double the distance, time and money.

3. Heavy customs tariff and irregular difficulties in the consular regulations hinder the national expansion of trade between such rich countries.

In regard to the cablegrams between North America and Spain it is expected that a new cable will produce before long a reduction in price and time.

The yearly direct commerce of to-day between the United States and the Iberian peninsula, without taking account of smuggling at Gibraltar, is:

| | 1881. |
|---|---|
| Spanish imports and exports, . . . . . | $19,967,026 |
| Portuguese imports and exports, . . . . . | 5,404,754 |
| | $25,471,780 |

No doubt, this commerce will be much increased with the reduction of the tariff in both countries, and improving the telegraphic and postal communications; but the present commerce is a sound basis on which to establish a direct and regular line of steamers between the United States and the Iberian peninsula.

The splendid ports of Vigo and Lisbon are within the extreme latitude of Boston and Baltimore. The distance from Vigo to the American ports is much shorter than the distance from Liverpool to Boston, New York, Philadelphia or Baltimore. The road from Vigo to New York is farther from danger of the icebergs than the road between Liverpool to New York, and less exposed to fogs and collisions at sea. In every season, but specially during the winter, the track from Vigo or Lisbon to New York will be more pleasant than the northern track. And always being the shortest crossing of the Atlantic, the New York-Vigo line will be the future line for mails and passengers between North America and central and southern Europe, making the voyage from New York to Vigo in 5½ days and from Vigo to Paris by rail in 1½, or the entire voyage from New York to Paris in one week. The well-known shipbuilders, Messrs. John Elder & Co., of Glasgow, on the eleventh of July last, wrote to me: "We have no doubt

that such a steamer as the *Umbria* could *easily* accomplish the voyage between Vigo and New York in the six days named by you."

This American-Spanish line will be the shortest, pleasantest, quickest and cheapest in time and in money for crossing the Atlantic from and to the majority of eastern states.

The tariffs must be arranged to allow the exportation all over the Spanish territory of the American cereals, bread, coal, wood, cattle and meats, and some other products wanted by the Spanish colony, and to allow at the same time, on the other hand, the importation into the American Union of wines, spirits, molasses, sugar, fruits, salt and other Spanish products required in the United States.

The English free-traders have written very eloquently against American protection. A prominent minister of England said that the great extension of the American territory saves this great nation from the ruin which would be carried by their tariff's system. But at the same time that those Europeans are right in preaching American free trade, they have forgotten the injuries of our European militarism.

I believe that this country would be richer under more liberal tariffs, but between the two evils, American protection and European militarism, I have no hesitation in declaring that the American system is less injurious.

The uniformity of tariffs over all the American territory is equivalent by the extension and different products to one union of customs (Zollverein) all over Europe. Nevertheless, the high American tariff is rapidly diminishing the national debt and increasing the population and national wealth. In Europe, militarism is only good for the privileged manufacture of war implements, but instead of diminishing, the national debts, the taxation, and the number of paupers are increasing.

Happy this great country without conscription, with 25,000 soldiers for 50,000,000 of inhabitants, and without dreams of conquest! Unfortunate Europe, with conscription, I say, with the slavery in the army for the white race, with millions of soldiers and millions of paupers, and always preparing for war!

Between the Spanish people, discoverers of America, and the energetic inhabitants of America there will be no war. Let us negotiate a treaty of international arbitration to submit all the

differences between Spain and America to an international tribunal. There have been made in Europe in late years nineteen treaties of commerce, with one clause of international arbitration. I rejoice to see that America is so inclined to a peace policy that the international arbitration system is introduced in one of the platforms for the next Presidential election.

I hope that before long a liberal treaty of commerce between the United States and Spain will open for both countries a market of 75,000,000 of inhabitants; and a new telegraphic system and a regular line of steamers between the United States and the Iberian peninsula will prepare a new era of prosperity for the time in which the inter-marine canal may be opened to the universal traffic.

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THE FUTURE OF THE UNITED STATES. By JOHN BIDDULPH MARTIN, M. A., F. S. S. (Delegate of the Statistical Society), London, England.

[ABSTRACT.]

THE century that has witnessed the development of the United States has been one in which the human race has effected a simultaneous revolution in the condition of social life; and the appreciation of chemistry, electricity and steam, to the purposes of daily use, has both stimulated and been stimulated by the expansion of the great western republic: we have before us the spectacle of a highly civilized race, occupying a territory apparently boundless in extent, at a period in the history of the world when all the material adjuncts to civilization are in their most expansive condition. Yet it is beginning to be recognized that if the recent enormous growth of population has not already brought us within a measurable distance of the time when the soil will be fully taken up, we are rapidly approaching a day when the conditions of life will begin insensibly to be affected by the growing pressure of population; in fact the fixed size of the country is the unstable pivot on which the whole machine turns.

Of the land area of the United States (3,000,000,000 sq. m.) one-third is taken as unavailable for cultivation; of the remaining two-thirds more than three-quarters is already taken "for settle-

ment;" of this 837,500 sq. m. are returned in the census of 1880 as farmed land, of which 443,750 sq. m. consist of improved land. There is, therefore, room for much labor before the full capacity for production of the land already taken up is reached, but it is clear that everywhere except in the far west there is little new land available for cultivation. Mr. Porter estimates this at 140.000 sq. m.; Mr. Griffin takes a more liberal estimate, at 400,000 sq. m. But in view of this fact that an addition of 5,000,000 to the population of the southern and western states, 10,000,000 to the far west states and 10,000,000 to the territories of the far west, would bring up their population to the present level of the thirteen original states, while the population is at present doubling itself in twenty-five years, there can be no doubt that this increase of 25,000,000 will shortly be attained. The first question is as to how this great population is to be fed. At the present rate of production America is able to export breadstuffs to 10,000,000 people outside her own borders; but if when all the land is taken up the rate of production were raised by improved agriculture to the English level, the surplus would suffice for 35,000,000. The development of American agriculture will have to depend on foreign markets for its products, and as the experience of England and America has been that food-supply is the regulation of population, it may be assumed that Great Britain will long supply a market for cheap American food-products. But in the meanwhile the urban population is growing relatively to the country population and the past may be expected to exercise a retarding influence on the development of agriculture.

This great population, and the supplies necessary for their use, will require increased means of transport. There was in 1880 a mile of railway in America to every 34.1 sq. m. of land area, and a mile of railway to every 569 inhabitants. It will necessarily follow that a large creation of bona fide railway securities must take place, but the decline in the rate of interest offered may affect the conditions under which they will be offered to the public.

The conditions of the public debt of America are without parallel elsewhere; the rapidity of its erection was unprecedented, but in spite of some uncertainties as to ultimate payment on a gold basis, the national securities found a ready market abroad. Since the national debt has been placed on a gold basis the advance that has been made in the reduction of principal and interest has

been gigantic; the charge for debt is now only ½ of the total revenue, as compared with ⅓ in the United Kingdom. It does not seem that this charge can fail to become, very shortly, altogether manageable, and to exist subject only to the duration of time for which it was contracted. At the same time the charges for naval and military purposes will become merely nominal, and the nation will be able to devote its whole energies to its own interests under the most favorable conditions that have been witnessed in the history of the world.

But the abolition of a national debt will exercise an effect on the general rate of interest, which will tend to fall in future as it has already done in the last few years; such a fall would be seriously felt by those who depend upon fixed incomes, a class which must tend to increase. It seems in consequence of this that there must be a tendency to a fall in wages and prices generally. Both manufacturer and consumer are interested in this, since cheaper raw material means cheaper production and consequently larger profit to the former, and competition will give some at least of the benefits of cheaper productions to the consumers. If we consider also the impossibility of spending the national income that may shortly be expected to accrue, it will not be unreasonable to expect a growing demand on the part of the great mass of consumers for emancipation from customs duties or imports.

Simultaneously with the increase of population and the diffusion of wealth, it may be expected that individual fortunes will in future be less easily made, and less formidable; gigantic operations in produce or stocks will be less easily worked, to the manifest benefit of the community; while the development of a leisured class will allow some of the best talent of the nation to be diverted to the pursuits of art, literature, science, and politics, to the incalculable advantage of the nation. It may be sanguine to expect any very rapid fusion of the United States into one homogeneous whole by the gradual federation of state rights; but the increased facilities of communication, the perpetual shifting of the population, and the transfer of enterprise from one state to another, must needs render irksome in an increasing degree the differences between state and state, as to marriage, bankruptcy and jurisdiction. The fusion of the United Kingdom is unfortun-

ately as yet incomplete, and the slow process of consolidation in the old country forbids us to be very sanguine in the hope of seeing the complete amalgamation of the United States in one federal republic.

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ON TECHNICAL EDUCATION IN THE BRITISH ISLANDS. By Prof. HENRY HENNESSY, F. R. S., Dublin, Ireland.

[ABSTRACT.]

GENERAL presentation of the views of the author as to the centres of technical education in England being best in the manufacturing towns instead of the university towns. Arrangements of the city guilds instituted in London referred to and criticised. The author referred to the conclusions of the recent commission on technical education, especially with reference to the application of the experience gained by their visits to the continent of Europe. To the condition of technical studies in Great Britain and Ireland. To the conspicuously imperfect state of technical education in Ireland; its causes traced from history and from facts coming under the author's observation and personal experience. Results of his visits to foreign countries compared with the results of the Royal Commission and general conclusions as to the future position of the scientific and practical study of technology.

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AN ACCOUNT OF "THE FIRST GENERAL CENSUS OF INDIA." By TRELAWNEY SAUNDERS, Surrey, England.

[ABSTRACT.]

THE first census that has been made for all India was taken on the 17 Feb., 1881. It is embodied in about twenty folio volumes, and the general abstract extends to three volumes folio. The paper commenced with a very brief description of the provinces and states which form the empire of British India. The entire population enumerated in Feb., '81, is 253,891,821. The area occupied by this large population is 1,382,624 square miles. The paper then proceeds to draw a comparison, extracted from the general reports, between various parts of this large population

and other countries of the world, chiefly European. As the occupied Indian house forms, as elsewhere, one of the bases of the return, the nature of the Indian house, especially in so far as it is distinguished from dwellings elsewhere, is described. The ordinary character of the furniture, the family arrangements, not only on European evidence, but on the evidence of a distinguished native as well, is entered upon. It is only doing justice to the nature of this vast work, to give only the barest possible reference to the headings of the tables comprehended in the census returns.

1. Area of population.
2. Movement of population.
3. Religious classification.
4. Proportions of sexes and religious divisions.
5. Condition of population.
6. Condition and age of population by religion and provinces.
7. Ages by religion and province.
8. Languages.
9. Birthplaces.
10. Education.
11. Insanity.
12. Blind people.
13. Deaf mutes.
14. Lepers.

15 and 16. Towns and villages.

17. Castes.
18. Occupations.

The reports in general are not merely a dry record of figures, but they abound with information of the most interesting character concerning this grand division of the population of the world, which stands second only in numbers to its still vaster neighbor, the Empire of China.

The author intimated that he had received instructions from the Secretary of State for India, to present to one of the public libraries of the United States, a copy of the General Report of the Census of India, in three volumes, folio. It may be useful to add for the information of students of statistics, that a statistical abstract, relating to British India, is printed annually by command of Her Majesty, the Queen, by Messrs. Eyre and Spottiswoode in London, at the price of one shilling and two pence.

NATIONAL IDENTITY IN ITS ECONOMIC ASPECTS. By LORIN BLODGET, of Philadelphia, Pa.

IT will greatly simplify many of the points of controversy and doubt as to economic policy, if we look at the laws of social and political organization under which nations exist.

It will be evident at the outset that we cannot apply any single or absolute law or rule, to the policies by which the best interests of the people are to be served. The civilized world is not a commune, nor is it a single community—to use two significant and expressive definitions—although it may have a system of interests common to all nations, and some elements of common responsibility on the part of individuals.

There is no common obligation of order, that can be enforced by a common police. There is no common treasury: and no common tax, or revenue. There is no common debt, obligation, or guaranty — no method through which to compensate any common service, or to maintain any establishment. How then can there be any common economic policy or any merging of the operations of one country with those of another as to the methods of raising revenue!

We are importuned to abandon the essential features of distinction which separate us from the English revenue system, because it is said that all nations should become brothers, and all trade should be free, but we have from the beginning raised our revenue chiefly by a tariff on imports, for reasons which the founders of the government found to be forcible and vital. The nation could not have been founded, in the first place, nor could it have been maintained in its early years at all, without this protective policy.

It must be understood as an axiom that no other than the most powerful nation can maintain itself without the regulation of its commerce:—first, by creating its own shipping or modes of communication with other countries, under its own national flag; and next by imposing limitations on external commerce, and laying duties on shipping as well as on foreign merchandise.

The idea has recently been broached that we may abandon our navy and dismantle our navy yards—indeed it is believed in some

quarters that we are already doing so. We have no ocean-going vessels of consequence and no foreign trade conducted by our own shipping. We have therefore no foreign interests, it is said, and should have no foreign policy.

Thus exempt from care and from responsibility, we may send the *Tallapoosa* to the bottom—to get rid of a surplus—and we may explode the latest torpedo—fortunately taking care not to kill anybody.

In short, we have been going on at some length in the process of denationalizing the country, and of reducing its government from one having a common share in the affairs of the world with other nations, to a mere domestic police—or we should have done all this if we had taken the advice of some very urgent friends.

It will be well worth while, therefore, to look carefully at the original reasons which enforce the existence of separate and mutually independent nations.

The highest possible type of human organization is found in the civilized nation, and the highest duty of enlightened human government is to establish and preserve the national identity.

The conditions which originally define or create the separate national existence, are in most cases beyond the reach of any directing hand; and the struggles of contending nationalities have written a history so full of calamities that it is reasonable to find a strong advocacy arising for the abandonment of many of the distinctions which mark the separate interests of nations. But the alternative course, or the breaking down of the limitations by which these separate interests are maintained, would bring on calamities incomparably greater than it would remove. Few would propose or attempt the political consolidation of nations historically distinct, whether made up of distinct races, or of such separate communities as have remained distinct for ages, with histories and traditions of their own for any long period. The mere contiguity of territory is no sufficient cause for merging one nationality in another, nor is a similarity of language, nor an original identity of race, if other and sufficient causes have erected a distinct and separate national existence, with its distinct government.

The civilized world cannot merge its separate nations into one community, nor is it desirable to do so; the highest incitements to activity would cease to exist, the sentiment of patriotism would be unknown, and the impossibility of establishing common

interests would react in such a manner as to break such a structure into a thousand fragments, over which the assertion of just and rightful authority would become impossible. It has been proved many times over that it is neither politic nor safe to undertake any contraction of long established national limits, nor any enforced political union of those who should remain separate. If the national spirit which we define as patriotism is not established and preserved in any community, the people will literally wither and waste. A nation may cease to exist, by decay of its resources, or by the extinction of its patriotic spirit. No greater calamity can be conceived than this waste of the national force, carrying with it, as it does, the ruin of vast numbers of helpless persons individually.

While the maintenance of the interests and the discharge of the duties inherent to the conduct of a nation, and especially such as are supremely important in its own defence, and for its own protection, the definition of these distinctive interests has recently become obscure with many publicists, because of the growth of new interests, which may be justly distinguished as international, or as being common to all nations; and there is also a considerable class grown up, outside of any nation, and without any sentiment of patriotic attachment to any country. It has been assumed that international comity may practically ignore the distinct identity of nations in many respects, and that restrictions which relate to trade and commerce may be dismissed from the list of national distinctions.

If this were attempted in any general manner, the consequence would be the wasting and disintegration of the weaker nations. If not reduced by such waste to a state of disorder, compelling the falling state to seek the protection of a strong one, the result would still be a material decline of power and prosperity. The most absolute and peremptory demand growing out of the fact of distinct existence, is for the separate organization of the productive forces of each nation. There cannot be an organization working in common, because the nations must each have a boundary. History is full of illustrations of the disruption of national boundaries, and the enforced submission of distinct peoples to a common rule; but all such violations of natural rights are at some later day restored and the nations are liberated, or the resulting ruin of the weaker victims surely follows. Europe is not a law to us, nor even an example, in most respects, be-

cause we hope to found here a more beneficent relation of the government to the people, one which will relieve them of the burdens of costly military armament, and of the perpetual strain of threatened wars. We have practically secured this exemption already, although with little time for rest, as yet, after the worst of our calamities has passed. But still we have no wasteful expenditures for war purposes, and no conscription of the people to fill up the army. The public burdens are very trivial in fact, and they are not felt as personal burdens imposed by the government in any case.

The analogy I draw here is that in nearly all that relates to the economic policy of nations, the right and the duty of distinct existence is as vital as is the like distinction of political power. The economic resources of all countries constitute and sustain their political power, and only those that develop their natural resources, and avoid the waste of that which they produce, can maintain power, or even secure the continuance of their separate existence.

Without organization and protection no one of the great natural resources of a state can be fully developed. The crude produce of the soil or the forest is never fairly developed in a dependent state; and the higher products of organized industry fall still lower in the scale. But when fairly brought into activity, the growth of social industries is rapid, and the profits or earnings of all classes become cumulative. The power of these social influences is better shown when the exchanges are made at the least cost. The densely populated state is more active than the scattered and disorganized population, and the industrial city affords as high a standard of productive force as the commercial centre does.

Every well organized nationality has its own centralization of forces, and it must preserve, develop and protect it, as the most necessary guarantee of its continued existence as a state. The first Act of Congress which established the revenue by which the loose confederation of colonies became a body of united states, passed by the first Congress on July 4, 1789, declared in section 1.

"*Whereas*, It is necessary for the support of the government, for the discharge of the debts of the United States, and for the encouragement and protection of manufactures, that duties be laid on goods, wares and merchandise imported."

And a discrimination in favor of "vessels built in the United

States, and which shall be wholly the property of a citizen or citizens thereof," was made by allowing an abatement of ten per cent from the duties imposed on that Act on merchandise, imported in foreign vessels.

It is the testimony of history, that, by this Act of July 4, 1789, and the subsequent acts of confirmation and continuance, the nation was as decisively created as by the earlier declaration that "the people of these colonies are, and of right ought to be, free and independent."

The best illustration of the position assumed in this paper is to be found in the history of the United States for the last thirty-five years. The vast resources which the central and western states are now found to have were at the beginning of this period almost unknown. Its national identity was so imperfect that foreign influences still controlled its trade, and its feeble industries produced but a small share of the necessary stock for its own consumption.

Now for a period of more than twenty years an intense national feeling has controlled the policy of the government, and directed the social forces of the people. The illustration of the present actual resources of the country, and of its accumulations during the national period, would be the most forcible of all possible statements.

I do not propose to enter on it, nor to undertake the definition of the public prosperity in the exact terms which should be employed. It is enough, here, to claim that the essential difference between the existing conditions and all former conditions is due to the concentration of public attention and private effort, or the duty of every national authority to carry out the laws which establish its own independent existence.

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SOME ECONOMIC AND SOCIAL EFFECTS OF MACHINERY. By EDWARD T. PETERS, Statistical Division, Department of Agriculture, Washington, D. C.

[ABSTRACT.]

THE prominence attained in recent times by what is briefly designated as the labor question is mainly due to the revolution that within a little more than one hundred years has been wrought in

the methods of production through the substitution of machinery for hand labor. The aggregate increase of wealth, which this change has brought about is prodigious, but how far the working classes have shared in this increase is a much disputed question. Statistics have been published to show that the laborer of to-day lives in much greater comfort than the laborer of say half a century ago; but such a comparison does not reach the essential question, which is whether the condition of the laborer has improved in a degree bearing some reasonable relation to the enormous increase in the productiveness of labor. Moreover it fails to cover the case from another and very important point of view. A considerable percentage of those who are wage laborers to-day owe to the change in methods of production the fact that they are such, and their condition should be compared not with that of the wage laborers of fifty years ago, but with that of the independent self-employing artisan of that time, whose position machine competition rendered untenable. So also there is a considerable percentage of the unskilled laborers of to-day whose condition should be compared not with that of the unskilled laborers of old, but with that of the skilled; for the reason that the supplanting of skilled by unskilled labor is one of the commonest effects of machinery.

But the question how far the working classes have shared in the increase of wealth due to improved methods of production cannot be answered by considering merely the portion of that increase devoted to subsistence. The wealth employed as working capital was formerly owned in great part by workingmen — artisans of the various classes who carried on business in their own workshops with their own tools and materials, but whose modern representatives (and in most cases probably their own descendants) are dependent on wages received from a separate capitalist class. Detailed statistics which ignore such circumstances as these and merely compare the condition of modern wage-receivers with that of similar classes of wage-receivers in former times may have an imposing air of scientific authority; but they obviously furnish only a single term in a complicated equation which none but a dunce or a charlatan would think of pretending to solve without attending to its other elements.

Taking into account the case of self-employing artisans who have been driven by machine competition into the wage-earning class, and that of the skilled laborers whose trades have been rendered useless in their hands by the same cause, there is good

reason to believe that, however great the general gain of society through increased production, there have been multitudes of individual workmen whose share in this gain has not been sufficient to compensate them during their lives for the injuries personally sustained by them. Doubtless the general good is the controlling consideration, but the incidental evils demand recognition, and the more society at large is benefited by machinery, the greater is its obligation to ward off, as far as may be possible, the injuries inflicted on special classes of workmen by changes in the methods of production. This obligation is all the stronger from the fact that the rapid progress of invention is not a purely spontaneous phenomenon, but is largely the result of patent laws expressly designed to secure it. Since governments thus interfere in the matter, they ought, if possible, to deal with the problem as a whole, and, while promoting the increase of machinery with a view to the extension of its benefits, to consider also how the attendant evils may be averted.

Of these evils that which is most serious and general is the divorce which machinery is bringing about between labor and capital. So far has this already gone that people have come to think of the two as things naturally distinct from each other, and to regard it as a normal state of affairs that the persons who perform the manual toil of a country shall be absolutely dependent for employment on a comparatively small class known specifically as capitalists, in whose hands are concentrated the implements with which alone modern industry can be successfully carried on. That such dependence is unfavorable to the highest type of manhood will hardly be questioned; and the enormous extent to which machinery has increased and is still increasing the percentage of persons subject to such dependence is surely a most serious matter. The manhood of a nation is its most precious possession, for the loss or deterioration of which no increase of material wealth can adequately compensate.

It goes without saying that the remedy does not lie in the direction of a return to the old slow methods of production. But if the workman may not again aspire to a separate business carried on with his own capital in his own little shop, he may reasonably aim at something which would constitute its economic equivalent, namely, the ownership of a proportional share of stock in some larger establishment.

The success attained in Philadelphia and elsewhere by the

coöperative loan associations, popularly known as building societies, shows that, under favorable conditions and suitable laws, coöperation may attain a large development, and gives some reason to hope that by proper effort its sphere may be extended until capital and labor shall, to a great extent, be again united in the same hands. The enactment of laws to render the combination of small capitals in industrial enterprise as easy, secure and convenient as possible would be a useful exercise of legislative power and one to which the extremest adherent of the *laissez faire* doctrine could take no exception.

This, however, is only a part of the question which machinery has pushed into the foreground. In so vastly augmenting the produce of industry, it has given a corresponding importance and urgency to the problem of its equitable distribution. Nor should we fail to note what it is doing in the direction of giving the political control of this problem to the wage-earning classes. By widening the chasm between labor and capital to a seemingly impassable breadth, it has given to workingmen the feelings of a permanent class bound to seek their separate interests as such; by concentrating them in large bodies in manufacturing cities and towns it has facilitated combination among them, increased their means of acquiring knowledge, and, in many ways, contributed to cement them together in one mass animated by the common purpose of securing for themselves a more liberal share in the advantages of civilization; it is still further promoting their union even where it seems most to injure them; for, by disintegrating the skilled trades, it is breaking down the partitions which selfishness had erected between different classes of laborers; and, finally, by reducing multitudes of independent tradesmen into their ranks, it has created among them a robust and combative element, such as would hardly have been found in a working class trained to patient endurance by generations of servitude, while by the same process it is also augmenting their numbers, so that it has made or is making them a majority in countries where majorities rule.

Under such circumstances it seems more than likely that what they resolve upon is destined to become the law of the land in the leading nations of the world. By one means or another they will seek a remedy for the ills which they believe that they unnecessarily endure and which many eminent thinkers — such men, for

example, as the late John Stuart Mill — have believed to be largely removable by means within the reach of social science. If the proper remedy were offered, it might commend itself to their reason and be accepted, thus averting the social disasters which must follow an erroneous method of treatment; but they will put no faith in any physician who shall tell them that the social body is in normal health, unless he can make good his statement by overwhelming demonstration. Whether disease exists, and, if so, what is its character and how should it be dealt with? are questions which demand the most unprejudiced and searching inquiry. Especially do they claim the attention of economic students, whose obligations to society in this connection are proportional to the facilities they possess for arriving at sound conclusions.

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ON THE APPLICATION OF THE HISTORICAL METHOD TO QUESTIONS IN ECONOMIC SCIENCE. By T. B. BROWNING, M. A., East Toronto, Ontario.

[ABSTRACT.]

THE paper raises the question, What is the historical method, and what application is it capable of in economic problems? *e. g.*, (1) as to land legislation and holding; (2) as to competition and combination; (3) the law of the market, or bargain and sale, or *caveat emptor;* (4) *laissez faire.*

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ON THE PROCEEDINGS OF THE SECTION OF ECONOMIC SCIENCE AND STATISTICS AT THE MONTREAL MEETING OF THE BRITISH ASSOCIATION. By CHARLES W. SMILEY, Washington, D. C.

[ABSTRACT.]

THIS paper consisted of an account of the papers read, and of the discussions thereupon.

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## On the credit of the United States Government. By E. B. Elliott, Government Actuary, Washington, D. C.

[ABSTRACT.]

TABLE

Showing the average prices (flat and net) of, and rates of interest realized to investors in the United States four per cent securities of 1907, and, in the four and a half securities of 1891, respectively, for each of the first eight months (January to August inclusive) of the calendar year 1884.

| 1884. | Prices including accrued interest. (Flat.) | Prices *not* including accrued interest. (Net.) | Rates of interest realized to investors. Per cent. |
|---|---|---|---|
| Months | Four per cent securities of 1907. | | |
| January | 123.7596 | 123.5897 | 2.670 |
| February | 123.8750 | 123.3809 | 2.677 |
| March | 124.1947 | 123.3705 | 2.675 |
| April | 123.7950 | 123.6354 | 2.659 |
| May | 121.6346 | 121.1434 | 2.778 |
| June | 119.8600 | 119.0292 | 2.880 |
| July | 119.9900 | 119.8178 | 2.838 |
| August | 120.1902 | 119.6944 | 2.842 |
| Months. | Four and a half per cent securities of 1891. | | |
| January | 114.3702 | 113.7953 | 2.497 |
| February | 114.5156 | 113.5761 | 2.570 |
| March | 113.5697 | 113.3863 | 2.534 |
| April | 113.5925 | 113.0359 | 2.564 |
| May | 112.8533 | 111.9377 | 2.700 |
| June | 111.0157 | 110.8494 | 2.836 |
| July | 112.4375 | 111.8770 | 2.672 |
| August | 112.7620 | 111.8350 | 2.659 |
| May, 1884. | Four per cent securities of 1907. | | |
| 1st to 14th inc. | 123.0052 | 122.6041 | 2.706 |
| 15th to 31st inc. | 120.4598 | 119.8915 | 2.840 |

| | Prices including accrued interest. (Flat.) | Prices *not* including accrued interest. (Net.) | Rates of interest realized to investors. Per cent. |
|---|---|---|---|
| May, 1884. | Four and a half per cent securities of 1891. | | |
| 1st to 14th inc. | 113.1250 | 112.2995 | 2.648 |
| 15th to 31st inc. | 112.6562 | 111.6090 | 2.745 |

The disturbance of values about the middle of May was due to a financial panic which then occurred.

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IRREGULARITY IN RAILROAD BUILDING, A CHIEF CAUSE OF RECENT BUSINESS DEPRESSIONS. By WILLIAM KENT, New York, N. Y.

[ABSTRACT.[1]]

THE author presents a table of statistics for each year from 1860 to 1883 inclusive, of miles of railroad built in the United States, of production of pig iron, iron rails, steel rails, and of rolled iron other than rails, of rail importations, of prices of pig iron and of iron and steel rails, and of immigration; also a plotted diagram made from the figures, which shows how the fluctuations in railroad building, in production, importation and prices, and in immigration coincide with each other.

He divides the twenty-four years, from 1860 to 1883 inclusive, into four periods: First. The period of moderate development, 1860–68, in which railroads built, pig iron and rails produced, and number of immigrants, all increased at an even rate. Second. The first period of violent development, 1869–73, inclusive, in which railroad building, pig iron and rail production, importation and prices, and immigration, all enormously increased. Third. The period of depression, 1874–78, characterized by diminished rate of railroad building, diminished production and greatly diminished prices of pig iron and rails, almost absolute cessation

[1] This paper is printed in full in the Iron Age, Sept., 1884.

of importation of rails, and greatly diminished immigration. Fourth. The second period of violent development, 1879–83, characterized by great increase of railroad building, of production of pig iron, of production and importation of rails, of immigration and of prices.

It is shown that the actual cost of railroads built in 1875 was more than $200,000,000 less than that of the railroads built in 1872; that the cost of rails produced in 1875 was over $47,000,000 less than in 1872; of rails imported $44,000,000 less, and of pig iron produced $82,000,000 less. The decrease in expenditure for railroad building of $200,000,000 caused the throwing out of employment of many thousands of laborers, the stoppage of mines, furnaces, mills and equipment shops of all kinds, diminished the incomes of those remaining employed, and consequently their purchasing power. The effect was continued distress throughout the whole commercial world. The author attributes the fluctuations of investments in railroads at the different periods named to the "insanity of capital," and shows that the too rapid building of railroads at one period and too slow building at another, is a sufficient and the chief cause of the depression of business of the years 1873–78, and also of that through which we are now passing.

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AMERICAN PRODUCTION FOR AMERICAN CONSUMPTION. By J. R DODGE, Washington, D. C.

[ABSTRACT.]

THIS paper shows:

1. The folly of attempting to feed the nations of the earth hewing their wood and drawing their water, and neglecting the organization of all constructive forces and the development of the highest skill in production.

2. That every nation must be practically self-supporting, making a few exchanges from an occasional surplus for a few luxuries that are inessential.

3. The consumption of the United States, the main stimulus of production, now and hereafter.

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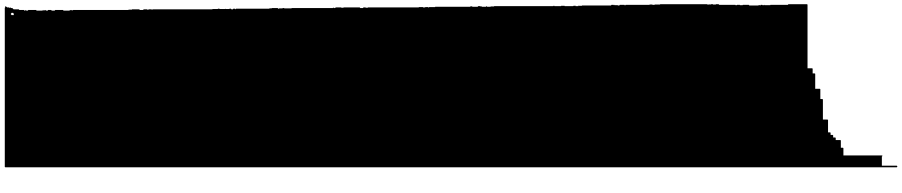

THE USES OF GREAT EXPOSITIONS. By LYNDON A. SMITH, Washington, D. C.

[ABSTRACT.]

THE exposition is like a museum, except in the necessary attendants of its short duration. The market uses have yielded to the ends of display and advertisement. Expositions do not pay for themselves directly. Their value is in (1) stimulating the development of natural resources; (2) the introduction of profitable industries; (3) the improvement of manufactures; (4) the increase of trade; (5) the founding of institutions; (6) the social development of people represented; (7) the advancement of science; and (8) the promotion of education, especially that of a technical character.

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THE LEARNED PROFESSIONS AND THE PUBLIC, 1870–1880. By CHAS. WARREN, Statistician, of the U. S. Bureau of Education, Washington, D. C.

[ABSTRACT.]

THE writer, deriving the number of persons engaged at the two census periods in the professions of law, medicine and divinity from the tables of "Occupations" published in those enumerations, showed that the rate of increase for each profession during the decade was much greater than the rate for the general population of the country; the marked increase in the number of clergymen of foreign birth, and the very great increase in the number of lawyers, particularly in the states north of the Potomac and Ohio rivers, were considered, and the deficiencies in American higher education as causes of these conditions were noticed. Admitting that the number of the clerical profession in this country is a matter purely within the control of sectarian necessities and not a matter for legal interference, the writer observed that there was precedent for considering lawyers as officers of the state and eminent propriety in passing laws to make physicians unpaid state officers also. When this needed relation of law and physic to the state is established and recognized, as, in the writer's opinion, should be at once, the qualifications of candidates for admission

thereto, the number needed for the supply annually of the public needs, and other points of detail, could be determined for the action of the state with little difficulty. The writer is of the opinion that both public economy and justice to the professions generally should take some such action in the case of these professions, in which he believes there was in 1880 a surplus of 64,000 persons.

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THE STRUCTURE AND ECONOMIC VALUE OF SOME OF OUR WOODS; ILLUSTRATED BY NINETY 8×10 PHOTO-MICROGRAPHS. By P. H. DUDLEY, New York, N. Y.

[ABSTRACT.]

THESE investigations upon the structure of the woods are principally for engineering purposes; the cells of the Duramen receiving the most attention, one important object being to ascertain the actual structure of the portion used. The 8×10 photomicrographs are all taken from original sections of the particular wood represented; the field of view of the objective covering about $\frac{1}{10}$ of an inch showing portions of one or more annular rings. Transverse, tangential, and radial sections are shown exhibiting the structure of vessels, ducts, tracheïdes, woody fibre and "medullary rays" in the various relations in which they occur, each magnified 100 times. 35 different woods are illustrated by the 90 photomicrographs. In some woods a favorable growth produces fibres which give the wood its specific value of hardness and strength; in unfavorable growths, there is an absence of the hard ligneous fibres, the wood being light brush and inferior in strength. This feature of growth as will be clearly seen by the illustrations is one of great importance not only in the selection of our present timber, but in considering the practical questions of forestry.

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AN ILLUSTRATION OF THE RESULTS PRODUCED BY THE ARTIFICIAL PROPAGATION OF FISH. By CHAS. W. SMILEY, Washington, D. C.

[ABSTRACT.]

THE illustration relates to the propagation of salmon in the Sacramento river, Cal.

Tables are given showing the annual catch from 1875–1883 and the number of young hatched and deposited from 1873 to 1882 inclusive.

The average annual increase due to artificial propagation has been 4,391,882 pounds. This quantity is worth $313,706, before any labor is expended on it. The cost of hatching and planting the 2,500,000 fry annually is $3,600. Hence the net profit due to fish culture is $310,106 annually.

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PERCENTAGES AND COSTS OF NUTRIENTS IN FOODS. By Prof. W. O. ATWATER, Middletown, Conn.

[ABSTRACT.]

THE relative cheapness or dearness of different foods must be judged by comparing, not the prices per pound, but the costs of the actual nutrients. In making such comparisons, the cost may be assumed to fall, not upon the inedible portions and the water, but solely upon the three classes of nutrients; protein, fats, and carbohydrates.

The relative physiological values of the nutrients in different foods depend upon (1) their digestibility and (2) their functions and the proportions in which they can replace each other in nutrition. An accurate physiological valuation is, in the present state of our knowledge, at least, impracticable. The pecuniary cost of the nutrients are, however, more nearly capable of approximation.

From extended comparisons of the composition and market prices of the more important animal and vegetable food-materials, such as meats, fish, flour, etc., those which serve for nourishment and not as luxuries and which form the bulk of the food of the people, it has been estimated that a pound of protein costs, on the average, five times as much, and a pound of fats, three times as much, as a pound of carbohydrates; that, in other words, these three

classes of nutrients stand related to each other in respect to cost, in the proportions:

Assumed ratios of costs in staple foods { Protein . . 5; Fats . . . 3; Carbohydrates 1

Suppose a pound of beef of average fatness to cost 25 cents and to contain 25 per cent of inedible matters, bone, etc., 45 per cent of water and 30 per cent of nutritive substance, upon which latter—the bone and water being assumed to be without nutritive value—the whole cost comes. The 30 per cent or $\frac{30}{100}$ pounds of nutritive substance thus costs 25 cts., or at the rate of 83½ cts. per pound. If now we leave out of account the minute quantities of carbodydrates and the mineral matters, the whole cost will fall upon the protein and fats. Assuming these to cost in the ratio of 5 : 3 and the amounts in the meat to be: protein 14¼ per cent, and fats 15 per cent, an easy computation will show the protein to cost 107.7 cts. and the fats 64.6 cts. per pound.—Proof: $\frac{14\frac{1}{4}}{100}$ pound of protein at 107.7 cts. = 15.3 cts. $\frac{15}{100}$ pounds of fats at 64.6 cts. =9.7 cts. 15.3+9.7 cts.=25 cts. the cost of the pound of meat which contained the given amounts of protein and fats. The above ratios, protein : fats : carbohydrates=5 : 3 : 1 represent at best only general averages and may in given cases be more or less incorrect. A method free from these objections consists in simply computing the amount of nutrients that may be bought for the same price in different food materials. At the same time the method above detailed is doubtless accurate enough for a general comparison of the relative cheapness and dearness of ordinary foods, and is used in calculating the costs of protein below.

Of the different nutrients, protein is physiologically the most important as it is pecuniarily the most expensive. In fish, furthermore, as in the leaner kinds of meat, it is the predominant nutritive ingredient. For these reasons the cost of protein foods may be used as a means of comparing the relative cheapness or dearness of ordinary foods, as is done in the following table. The figures represent the ordinary prices per pound and the corresponding costs of protein, in specimens of food-materials obtained in New York and Middletown, Conn., markets. Though the number of specimens is too small for reliable averages, the figures taken together, doubtless give a tolerably fair idea of the relative costliness of the nutrients in the different classes of foods.

COMPARATIVE COSTS OF PROTEIN IN FISH AND OTHER ANIMAL AND VEGETABLE FOODS.

One Dollar=100 cents = 4 Shillings = 4 Marks = 5 Franks, nearly.

| FOOD MATERIALS. | AVERAGE PRICES per lb. | A POUND OF PROTEIN COSTS | FOOD MATERIALS. | AVERAGE PRICES per lb. | A POUND OF PROTEIN COSTS |
|---|---|---|---|---|---|
| | $ cts. | $ cts. | | $ cts. | $ cts. |
| Beef, sirloin, medium fatness | .25 | 1.06 | Halibut | .15 | .85 |
| Beef, sirloin, at lower price | .20 | .86 | Mackerel | .10 | .79 |
| " round, rather lean | .18 | .70 | " when abundant | .05 | .40 |
| " " lower price | .15 | .59 | Cod | .08 | .75 |
| " corned, lean | .15 | .55 | " when plentiful | .06 | .56 |
| Mutton, leg | .20 | .82 | Alewife | .03 | .27 |
| " side, medium fatness | .15 | .55 | Canned salmon | .20 | .70 |
| Pork, very fat | .16 | .33 | Salt mackerel | .125 | .53 |
| " " " lower price | .12 | .25 | Salt cod | .07 | .43 |
| Smoked ham | .15 | .43 | " " lower | .05 | .31 |
| Milk, 7 cts. per quart | .03½ | .53 | ——— | | |
| Cheese, whole milk | .18 | .37 | Oysters, 30 cts. per quart | .15 | 2.02 |
| " " " lower price | .13 | .27 | " 50 " " " | .25 | 3.36 |
| " skimmed milk | .08 | .18 | Lobsters | .12 | 2.02 |
| ——— | | | ——— | | |
| Salmon, early in season | 1.00 | 5.11 | Wheat flour, best | .04 | .15 |
| " when plentiful | .30 | 1.53 | Wheat bread | .06 | .29 |
| Shad | .12 | .99 | Corn (maize) meal | .03 | .12 |
| " when abundant | .08 | .66 | Oatmeal | .05 | .15 |
| Blue fish | .10 | .98 | Beans | .05 | .14 |
| Haddock | .07 | .84 | Potatoes, 50 cts per bu. | .009 | .14 |
| | | | Potatoes, 100 cts. per bu. | .017 | .30 |

Thus the nutrients of vegetable foods are, in general, much less costly than in animal foods. The animal foods have, however, the advantage of containing a larger proportion of protein and fats, and the protein, at least, in more digestible forms.

Among the animal foods, those which rank as delicacies are the

costliest. By the above calculations, the protein in the oysters costs from two to three dollars, and in salmon, rises to nearly six dollars, per pound. In beef, mutton and pork it varies from 108 to 48 cents: in shad, blue fish, haddock, and halibut the range is about the same; while in cod and mackerel, fresh and salted, it ranges from 67 to as low as 33 cents per pound. Salt cod and salt mackerel are nearly always, fresh cod and mackerel often, and even the choicer fish, as blue fish and shad, when abundant, cheaper sources of protein than any but the inferior kinds of meat.

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THE APPRENTICESHIP QUESTION AND INDUSTRIAL SCHOOLS. By THOMAS HAMPSON, Bureau of Education, Washington, D. C.

[ABSTRACT.]

THE object of this paper was to inquire (1) whether the apprenticeship system of the United States provides our manufactories with an adequate supply of trained workmen; (2) whether if it does not the system may be so modified and extended that it will; (3) if the system is incapable of adaptation to current industrial needs, what is to replace it? The history of the relation of master and apprentice was first briefly sketched and its present condition then described, the writer seeking to show that the first two questions must be answered in the negative. Respecting the third, he urged the substitution of scientific for literary studies in the common schools and the establishment in manufacturing cities of manual labor schools to be attended by volunteer classes from the public schools.

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CONDITION OF DEAF-MUTES AND DEAF-MUTE INSTRUCTION IN THE UNITED STATES, STATISTICALLY CONSIDERED. By Prof. J. W. CHICKERING, jr., Deaf-Mute College, Washington, D. C.

[ABSTRACT.]

THE proportion of deaf-mutes to the whole population varies somewhat in different countries, but is on the average about 1 to 1500.

This would make the deaf-mute population of the world, according to the most recent estimate, 1,082,182.

In the United States the last census gives the total number of deaf-mutes as 33,878. Of these about 12,000 are of school age, of whom 7,155 are under instruction, leaving 5,000 growing up in entire ignorance.

It is also estimated that over 15,000 have received an education, and are engaged in the ordinary pursuits of life, while the remainder, between one and two thousand, are adults, for whom nothing has been done.

For the education of these 12,000 of school age, there are 58 schools, public and private, and one college. In 8 of these, instruction is given by the pure oral method, in 10, by signs and the manual alphabet alone, and in the remainder, by the combined method.

The condition of educated deaf-mutes is quite satisfactory. They are self-sustaining, self-respecting, valued members of society.

The uneducated deaf-mute can find but little enjoyment in life, is a burden upon society, and his claims upon the philanthropist, the student of political economy and the patriot, should not be disregarded.

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UPON THE EXPEDIENCY OF A PROPOSED "NEW DEPARTURE" IN THE FORM OF SCHOOLS FOR THE EDUCATION OF DEAF-MUTES. By JOSEPH C. GORDON, Professor of Mathematics and Chemistry, National Deaf-mute College, Washington, D. C.

ABSTRACT.

THE paper notes the claim that "the most practical, useful and economical form of school to be established (for deaf-mute children) would be, to form classes for them in Public Schools," and presents cumulative evidence against the expediency of the so-called "new departure" by a dispassionate recital of the history of the attempts to educate deaf-mutes in Public Schools in Western and Central Europe, from the year 1815 to the present time. It shows that persistent efforts, varying so greatly in detail as to cover almost every conceivable phase of this question, and employing all the

known resources of the art, as set forth by the advocates of various methods, systems, and devices of instruction had been made upon a large scale by able and enthusiastic men, and that the power of great governments had been exerted to qualify teachers and equip schools, but those plans were not found to be efficient, sufficient, or economical.

Among the authors and promoters of plans of education of the deaf, in connection more or less intimate with the common schools, whose views were cited, were Stephani, 1815; Alle, 1820; Daniel, 1825; Dr. Graser, 1829–34, and 1843; Czech, 1836; Wich, 1842; Schwartzmaier, 1850; Minister at Berlin, 1828; Saegert, 1854; Moritz Hill, 1858; Walther, 1882; De Gerando, 1827; Bebian, 1827; Recoing, 1823; Piroux, 1830; Valade-Gabel, 1851–54; Dr. Blanchet, 1836; Minister of Interior, Paris, 1858; Grosselin, 1870; Paris Congress, 1878; Bordeaux Congress, 1881; Arrowsmith, 1819; etc.

In the article, the foreign authorities, after a careful reading of the originals for the most part, are cited in English for the first time, and in conclusion, the writer feels justified in affirming—

1. That all the material conditions of the proposed "new departure" in America, have their parallel in the European experiments.

2. The satisfactory education of those born deaf demands special knowledge, special training and special methods, which are not possible in common schools.

3. Literal co-education of those born deaf, with hearing children is an admitted impossibility.

4. Deaf children, prepared by special instruction to join regular classes in common schools without detriment to themselves or to their classmates, rarely need common school instruction, having incidentally accomplished the work of the common school in gaining the knowledge of language and ease of communication essential to success.

5. "Mixed" schools, with separate classes under the same instructors, overtask the teachers and involve a waste of time by both classes of pupils.

6. The social, intellectual, moral, and material advantages of association with hearing children in the public schools are largely illusory, the environment being, substantially, the same as that of all deaf children before leaving their families to enter special

institutions. The hearing environment must be selected with extraordinary care to secure any good result from it.

7. Parents and public school teachers can readily qualify themselves to render valuable help to deaf-mutes, by beginning their education, and supplying, as far as possible, the training corresponding to the maternal education of infants, and the earlier part of the work of kindergarten or infant schools.

8. The fair results, sometimes obtained outside of special schools, have been rare, and under exceptional circumstances.

9. No satisfactory plan has ever been found for supplying deaf classes in public schools, with teachers having the special fitness, knowledge and training, requisite for the satisfactory education of those born deaf.

10. Day-schools or *externats* for the deaf, whether special schools alongside of public schools or entirely separate from them, are not so efficient as the better class of thoroughly organized institutions many of which have grown out of day-schools.

11. Special institutions remain a necessity for the great majority of deaf children and they continue to show superior results with the greatest economy of time, money and men, irrespective of method, system, or devices of instruction.

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## LANDS IN SEVERALTY TO INDIANS; ILLUSTRATED BY EXPERIENCES WITH THE OMAHA TRIBE.

By Miss ALICE C. FLETCHER, Peabody Museum, Cambridge, Mass.

ACCORDING to the report of the Commissioner of Indian Affairs for 1883, the total number of Indians in the United States, exclusive of Alaska, is given as 265,565.

The amount of land reserved for Indian occupancy is stated at 143,526,540 acres; of this, 125,639,725 acres are untillable, leaving 17,886,815 acres fitted for agriculture.

The same report gives 630,960 acres as under cultivation by 40,145 Indian families.

10,226 families are stated to be engaged in other civilized pursuits.

At the average of five persons to a family, we find that of the

265,565 Indians in the United States 200,725 are engaged more or less in farming, 51,330 in other civilized pursuits and 13,510 gaining their livelihood by fishing, hunting, root-gathering and government rations. A large proportion of this latter number live in regions where life can hardly be sustained in any other manner. Concerning some of these localities it has been wittily said that "not even a rabbit could live there except at government expense."

More than two-thirds of the Indian population are shown to be already engaged in farming; the question of land tenure in therefore of practical importance, not only to the Indian, that he may enjoy permanent benefits from his industry and progress in self-support, but to our own people, since the future interests of the two races are closely interwoven.

Mr. Lucien Carr, Assistant Curator of the Peabody Museum,[1] Cambridge, Mass., says of the Indians as agriculturists: "All the records tell us that the early colonists in New England, Virginia and elsewhere, throughout the eastern portion of the United States, owed their lives on more than one occasion to the timely supplies of corn begged, bought or stolen from the natives . . The testimony is uniform of the cultivation of corn in greater or less quantities by all the tribes living east of the Mississippi and south of the St. Lawrence and Great Lakes . . and instead of cultivating it in small patches as a summer luxury it can be shown on undoubted authority that everywhere within the limits named the Indian looked upon it as a staple article of food both in summer and winter: that he cultivated it in large fields and understood and appreciated the benefits arising from the use of fertilizers; indeed, such were his proficiency and industry, that even with the rude and imperfect implements at his disposal he not only raised corn enough for his own use, but, as a rule, had some to spare to his needy neighbor, both red and white." Many instances are given, setting forth the great quantity of corn raised as the invasion of four villages of the Senecas by the French under Denonville in 1687, when 1,200,000 bushels of corn were destroyed, the people taking it quietly remarking that the other Iroquois natives were able to make the loss good. Mr. Carr com-

[1] Kentucky Geological Survey, Vol. II, "Mounds of the Mississippi valley historically considered."

bats the fellow of the agricultural error, which is "that the Indian considered field labor as derogatory and left it to the women." He brings strong evidence to show that the Indians of the Mississippi valley lived in fixed villages which they were in the habit of fortifying by palisades; that they raised corn in large quantities and stored it in caches and granaries for winter use; and that while it is a fact that "the women, children and old men and slaves always cultivated the fields, yet the warriors cleared the ground, and when not engaged in war and hunting aided in working and harvesting the crop, though the amount of such assistance varied, being greater among the tribes south of the Ohio and less among the Iroquois or Six Nations. By the testimony of the same early writers it can be shown that the rights of property were duly recognized and respected, and that there existed among the Indians a system of intertribal traffic."

The historical statements collated by Mr. Carr are corroborated by existing customs among the tribes formerly dwelling east of the Mississippi, and a remarkable substantiation of the truth of early observers is found in the fact already cited, that two-thirds of the entire Indian population are to-day engaged, more or less, in agriculture. In this connection it should be remembered that most of the tribes living east of the Mississippi have suffered more or less forcible removal from the homes of their fathers, and that the uprooting of a people dissipates both courage and enterprise. Agriculture, therefore, must have been a familiar occupation to these Indians for many generations, or it would not thus persist under adverse circumstances.

The Indians of the plains who lived almost exclusively by hunting, the territory they inhabited not being naturally adapted to agriculture, have within the last ten or fifteen years given notable instances of a willingness to farm, and a desire to be instructed in agriculture and to own their lands individually. The Crows of southern Montana, who are beginning to farm, have a tradition that their people once raised corn. All the Indians, even those who did not have the cereal, when first met by the white men, evince a great liking for corn, and desire to possess it for food. There is not an Indian tribe within the limits of the United States living on land susceptible of agriculture, by irrigation or otherwise, but that has some land under cultivation, and, as all the reports

of the Indian Bureau go to show, an increase in this amount depends largely upon the encouragement, instruction and assistance received from those having the Indians in charge.

It is but just to the government officials to say that their willingness generally far outstrips their means, the appropriations by Congress falling far short of the requirements necessary to push the Indians forward to self-support.

It is frequently taken for granted, that because the Indian in his native condition did not connect the abstract idea of property with the land, therefore he regarded the land as belonging to the tribe in common, the individual merging his right in that of the community; and, also, because the land was recognized by the Indian as a religious symbol and reverently addressed, the Indian was averse to using it, and to owning it individually. Unfortunately both these errors have been commonly accepted as facts.

It is difficult to explain briefly the relations of the Indian to Nature, and yet some knowledge of this relation is needful to a correct understanding of his mental, social and religious habits. To the Indian no aspect of nature is clearly defined from his own life, but is rather a part of it, or, he a part of nature. The elements, all vegetable and animal forms, are important and almost equally potent, and are linked in some mysterious way to his actions, and even his very existence. Relationship is the basis of Indian society, and constitutes the one tie which cannot be broken, which must always respond to an appeal or obligation, therefore the Indian seeks to propitiate, placate, win to friendliness and help, the elements and the varied forms of life, by addressing them in terms of the closest relationship, as Father, Mother, Grandfather, etc. The corn is called "Mother," for nourishment is received by it. The earth is addressed as "Grandmother," since all things come from it, etc. This manner of regarding nature is not conducive to the development of the idea of holding land as property, of placing a money value upon it, and passing it from one buyer to another as one would a garment. It was both natural and habitual for groups of Indians to remain within certain localities, to cultivate the soil in fields of greater or less extent, and use the land for the maintenance of life.

They argue: "The life of man depends upon the earth, he cannot live away from it, how then can one person own land to the exclusion of other men?" Why should not men claim to own the air,

or the water, which are equally necessary to life?" Slowly the white man's estimate of land is forced upon the Indian mind, and while it is not yet fully understood, it is accepted by him as the interpretation which must control the future. This acceptance has come about through terrible tragedies which have thrown shadows over the history of our country. Happily the story of the Omaha tribe is not one of this sad class, although it illustrates the historic facts of the relations of the Indians to the land, and also the advisability of allotting to him lands in severalty.

The Omaha tribe formerly lived in fixed villages composed of earth and timber lodges, and cultivated the soil, raising corn, beans, squash and melons. The agricultural work was chiefly conducted by women, although, when necessary the men assisted. The time of planting was regulated by a religious custom. A few kernels from a perfect ear of red corn, were distributed among the different households by the keeper of the sacred tents of the Hunga gens, and these kernels were mixed with the seed for planting, which then took place. Sheltered valleys and bottom lands were favorite places for cultivation. The same family used the same piece of land for years, occupancy being always respected. If a family abandoned a field another might then use the ground. There were always some persons more thrifty than others, who secured better fields, and consequently raised larger crops. No corn was cultivated as a tribal product, nor were there stores of any kind held in common. All possessions were individual, family property could hardly be said to exist, even the belongings of a child were respected by its parents and relatives. During planting and harvest, relatives were expected to help one another but this was not obligatory.

The Omaha Reserve lies in the state of Nebraska, on the west bank of the Missouri, about eighty miles north of the city bearing the name of the tribe. The people have been in this region for more than a century. Although driven by wars, west to the Elkhorn river and as far south as the vicinity of Lincoln, the capital of the state. These Indians have clung persistently to their villages on Omaha Creek and its tributaries. In 1855 they made their first separate treaty with the United States and ceded their hunting-grounds lying between the Nebraska and Platt, a range not far from 200 miles north and south, and 300 east and west. In this treaty they negotiated to have their land allotted in severalty. As

the agreement was not carried out, their treaty of 1866 contained a distinct provision for the survey and allotment of the land to those members of the tribe living at that time upon the reservation. Accordingly the reservation was surveyed in 1868, and within the next three years 331 certificates of allotment were issued. About ten years ago the tribal village was abandoned, and the work of agriculture began in earnest. The extinction of the buffalo herds made the raising of corn and wheat of paramount importance, as henceforth the people must depend upon the products of the soil as the sole means of obtaining their entire supply of food, clothing, and all the necessities of living. The purchase money due the tribe was paid in yearly instalments of the principal, and a portion of the payments was devoted to the purchase of wagons, harness implements, etc.; these were of great help to the people now engaged in the struggle of self-support.

When the Poncas, a kindred tribe, were being taken by soldiers to the Indian territory from their home on the Nebraska, where they had built houses and opened farms, the Omahas visited their relatives as they were en route south. Their distressing circumstances startled the Omahas out of their feeling of security on their allotted lands. To make sure of their own land tenure, lest they too might suffer such an expulsion, some of the progressive men took their certificates of allotment, which they had always supposed to be patents, to a lawyer for examination. When the Indians heard that the certificate granted occupancy only, and gave no title to the land, not a thoughtful man among them but dreaded the morrow. Unable to speak directly to the authorities, conscious of being misunderstood and disliked by the white people, distrusting all officials, the Indians felt themselves helpless in the grasp of a power to which they could neither reach nor appeal. In the face of this dismay, it is a wonder they continued to work and improve their farms which they could not own.

When the writer went among the tribe to study their life and customs they were found in the midst of this sore trouble; passing from family to family, seeing their efforts, feeling their sorrow, it was impossible to do otherwise than to seek some means by which to bring them help. Statistics of their work were gathered and these showed beyond cavil that a large portion of the tribe had practically homesteaded their farms, and thus had a just claim for a patent, aside from any plea of sentiment or abstract right to the

land of their fathers. The effort to secure their land based on this claim was successful, and on Aug. 7, 1882, the President signed the bill granting the Omahas patents to their lands in severalty. In May, 1883, under the authority of the Secretary of the Interior, the writer began carrying out the provisions of the bill, and completed the work in July, 1884.

The bill gives to each head of a family 160 acres. Orphans and single persons of eighteen years and over, 80 acres. All persons under eighteen years, 40 acres.

Nearness to market, and land fully fitted to agriculture are essentials to successful self-support. The Indians were urged to take their lands when these two important points could be covered. The tribe were mostly scattered in the valleys of the bluffs of the Missouri, and 10, 20 or 30 miles from market and consequently suffering from many disadvantages. Their fields were small, and often subject to the sudden rise and overflow of the stream. To encourage the people to make this desirable change the writer's first camp was pitched in the fertile valley of the Logan, through which the Omaha and Sioux city railroad runs following the stream. The people in large numbers soon gathered there and each day was spent going about with the Indians, aiding them in their selection of lands, and advising them as to the work of starting their new homes.

In the two townships through which the railroad passes, and in the two adjoining townships to the eastward, 326 allotments were made; 69 were to heads of families, 58 to single adults, and 199 to persons under 18 years of age. This remarkable exodus shows the spirit of the people, and promises well for the future. Nearness to market is secured, and the finest land on the reservation is now possessed individually by many of the most progressive families in the tribe. Already on these allotments something like 700 acres of prairie have been broken, trees planted, and in a few instances, crops gathered, and several houses have been built.

During the allotment of the lands a surveyor reëstablished the corners of sections where needful and each Indian was made familiar with his landmarks and as far as possible taught the use of the township plats. An outline of our laws of property and legal descent were explained. These were difficult to make clear to the comprehension of the people, owing to ancient tribal customs.

The money value of different locations was no incentive to selec-

tion. All arguments were generally met with the saying; "That may do for the white man, who does not love the land and is willing to part with it, but it is different with the Indian. If the land is good and near to the market, I must keep the land if I would have its value. Should I sell the land, I would have nothing to live on, and what difference then to me, its price?"

Considerable formality was arranged to attend the signing of the paper of selection, from which the patent was to be made out. Each man and woman signed his or her name or made the mark, in the presence of witnesses known to the signer, and the reason of this formality explained. Each Indian was thus brought into direct and intelligent responsibility with his or her choice of land, and taught the importance attached to the signing of a person's name and the guards placed about the act by our forms and customs. The use and destination of the signed papers were carefully explained as well as the series of checks instituted by the government to insure against mistakes. To do the work in this manner took time, but it has left a permanent value among the people.

Prosperity and social growth depend largely upon the stability and security of the family. Indian customs pertaining to marriage and divorce do not conform to the general laws of our country. When the ancient Indian social usages were in full force and vigor, the integrity of the family was fairly maintained, but the loss of the old restraints has never yet been made good by the substitution of our protective legal forms.

In order to prepare the way for a better social order and at the same time furnish the data for the legal inheritance of the land, as provided for by the Act of Congress under which the allotments were being made, a full registry of the tribe by families was prepared and indexed, giving the name of each member and their relationship, and also the number of each allotment of each individual. This number was also placed upon its proper section and subdivision on the township plat. The registry and the plats thus complement and explain each other and will afford the agents the means to intelligently and effectively maintain the family relation and secure the proper descent of the land. Ample space was left in the registry book for the formation of new families, and the Indians urged to report each birth and death and marriage for registration in order to secure the full rights of the land. In view of the pe-

culiar difficulties attendant upon obtaining exact information concerning Indian families; difficulties arising out of social customs, such as it being improper to mention the names of certain relatives and the complicated and extended Indian relationships, the establishing of this complete registry of families was one of the most important acts connected with the work of allotment.

75,931 acres were allotted in 954 separate allotments to 1,179 persons. About 55,450 acres remain to the tribe for the benefit of children born during the next twenty-five years, the period of trust or guardianship vested in the United States.

The tribe at present has between 6 and 7,000 acres under cultivation and raise in round numbers about 100,000 bushels of corn, 50,000 bushels of wheat, 30,000 bushels of vegetables and other small grains, and put up over 30,000 tons of hay. An Omaha, and not one of the largest farmers, raised, last year, 1,800 bushels of corn beside a good crop of wheat and vegetables. Another man sold over 800 bushels of potatoes, of excellent quality, and he also raised a very large crop of wheat, corn and other grain and vegetables. It should be stated that both these instances are given where all the work was done by one man, with such help as his wife and young children could render, the older children being at school. It is seldom that more than two men work on a farm and there is not a hired laborer on the reserve.

Assigning the land in severalty is comparatively easy when the region is one fitted to agriculture. 160 acres of prairie can be definitely calculated to produce certain crops and income, but there are vast tracts on Indian reservations which must be divided differently: for instance, the arid region occupied by the Navajo tribe. These Indians are self-supporting by sheep-raising and their present territory is fitted for little else; equitable division of their land must be based upon other calculations than prairie land. So, too, of the regions in Montana and other western territories, where water is as great a need as land, all crops being dependent upon irrigation. Again, the fishing tribes of the Pacific coast present another aspect; none, however, offer obstacles which can not and should not be overcome. The Indian crisis is upon us and a delay of a few years will find the task made more difficult. For the benefit of all concerned, the Indian should be given his just and individual rights to the land, to the law and to education. He is asking it and, as far as his power of discern-

ment goes, using it. Chiefs oppose because land in severalty breaks up completely their tribal power and substitutes civilization and law.

It is clear beyond cavil that the Indian must die or become absorbed in the body of citizens. That he is not likely to die out is shown by the fact that he is already on the increase; therefore, citizenship with its duties seems to be his appointed end, and he stands in need of preparation to meet his coming fate. It is hugging a delusion to suppose that any distinct Indian nation or nations can exist within the limits of the United States; that question has been settled for men of all colors and races.

Reservations took rise partly through the fears and hatreds bred of race conflicts, and while they have had their uses they are not adequate to the task of fully civilizing the Indian tribes. What the Indian needs is that which every man needs: opportunity for experience, the freedom to make mistakes and suffer from them, the urgency of necessity to stimulate and secure individual and social growth. These conditions do not and can not exist under the isolation and protection of the reservation system. The best schooling for the Indians is to mix with and live with the white people, and those who know the Indians best do not find them bad neighbors. Nor are the Indians apt to suffer so much from white settlers as from the roving adventurers who find immunity from law near the reserves. The larger reserves which lie scattered over the country are harmful in their influence; the stretches of uncultivated land often block the path of enterprise. As the Indians have neither the training nor capital to open up the country, and the white men are tempted to acts of injustice to become possessed of the unoccupied territory, it would be for the advantage of civilization to break the reservation up and make possible the conditions under which the Indians can become self-supporting.

Such a procedure would be but just to the more than two-thirds of the Indian population who are to-day trying to engage in agriculture. They should be given their lands in severalty, the title thereto being properly secured for a term of years, and the remainder of the reservation should then be thrown open to white settlement. The Indians would thus be brought into daily contact with every-day, civilized living with its various activities, its opportunities for advancement, and its educated public opinion which

recognizes the value of labor. Better acquaintance and better understanding between the red and white man would follow. Industry would find its reward, and the law would protect friend from foe. By no other method can the two races be safe with each other in the land where they are fated to dwell together. The Omahas are not an exceptional tribe, except in the fact that they have never suffered a removal. Other tribes of like enterprise should have a like reward of titles to their lands, for their efforts toward civilization, made in the absence of any social stimulus, for all their efforts have been individual, and not communistic.

While the Indian has not in his native thought the abstract idea of property in law, he is nevertheless accustomed to use the land, to cultivate it individually, to be secure in the fruit of his labor; similar results can only be obtained among us by individual legal land tenure. For the possession of this right, the different tribes urge strongly their claim through their only official organ, their agents. Every report of the Commission of Indian Affairs gives ample testimony to this statement. The general condition of advancement of the Indians hardly warrants giving them to-day a fee-simple title to their lands. A large portion are still struggling with the task of acquiring a new language, new methods of thought, new modes of living, and the confusion incident to the removal of ancient landmarks; but none of these conditions are in the way of giving to many tribes their lands in severalty, the patents being held in trust for a limited term of years. All candid observation bears out the remark of the Honorable Commissioner, that "in no case where allotments have been made and the title secured with proper restrictions have any other than the best results followed."

That the words of the Indian himself upon self-support may be heard, the following quotation is taken from an appeal sent through the writer by the Councilmen of the Omaha tribe to the Commissioner of Indian Affairs.

"We want to go forward by our own exertions; to make this sure, to have the way clear before us, we say, that as long as the Government sends us employés we never can work for ourselves. We want the Government to let us become fully self-supporting. We want our children educated; some are being educated away from the Reserve, others have already learned trades, these latter can open shops for themselves, and we can employ them and pay them for their work. We can learn much faster by striving for

ourselves than in any other manner. This is the way the white people do, each man struggles for himself and his family, and owns his property. The Government does not deal with us as with individuals, and even the implements are sent to the tribe. No one takes care of them for each one says, 'they are not mine.' We do not wish this done any more. It is not good for the people. We wish to buy our own implements. The money is now eaten up fast by the officials. They may try to do right, but they do not satisfy us. They do not tell us of the money expended, they do not tell us what is paid for different articles, and we are kept in ignorance of our money affairs. As to what is needed to be bought, all the people are not of one mind. It would be better if each person selected and bought his own implements, he would learn more and improve faster if he acted for himself. Our money is now all expended for us. This is unjust, we do not wish it to continue. It seems to us that the Government has given us things as playthings are tossed to children, to be used by all of them as something in common. The money so used is wasted, because there is no individual care or interest, no one owns anything. If we could speak to your friends in the East, we would say, 'We desire to be treated as men, not as children, so that we be listened to, and our wishes considered.'"

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AMERICAN PEARLS. By GEORGE F. KUNZ, New York, N. Y.

[ABSTRACT.[1]]

PEARLS are produced by the accidental lodgment of foreign bodies within the shell, such as grains of sand, one of the eggs of the mollusk itself, or a minute cercarian parasite, penetrating and irritating the mantle. The animal is not able to remove this foreign body and it soon becomes encysted, or covered as by a cap-

[1] This paper is only preliminary. In the near future the pearl will be investigated chemically and microscopically, and a sure vantage ground will be furnished. In the following article little reference is made to the species as the list is incomplete. Moreover, the author has in view a treatise containing full and authentic references to the early American explorers, a complete list of those species that have been thoroughly

sule, which gradually thickens assuming various forms, round, elongated, mallet shaped, etc., as regular as though they had been turned in a lathe.

Mr. C. L. Tiffany suggests that the animal attempts to rid itself of the irritation by continually revolving the enclosed particle, or, possibly, that a motion natural in a degree is accelerated by the intruding body. Mr. Tiffany has carefully examined a large percentage of American pearls of all forms and sizes.

None of the air-breathing mollusks, such as land and sea snails, produce a nacreous shell, and among fresh-water mollusks none of the air-breathers are pearl-bearers,[2] nor those which breathe by gills, except a portion of the bivalves, especially those belonging to the group typified by our common river mussels, which are appropriately called the Naiades.

The soft internal part of these mollusks is covered by a thin delicate membrane called the mantle, by the surface of which, and particularly the outer edges, the secretions are furnished to make the shell and are more lustrous and dense than the shell itself. This shell has two principal parts, the epidermis and the shell proper, the latter having several layers. The epidermis is of a horny texture, chiefly composed of a substance called conchioline, which is entirely dissolved by a caustic alkali.

### LUSTRE.

Many of the pearls are a dead white. These are of little value. But the fine ones owing to their delicate "skin" or layers are at times more lustrous than even the finest oriental pearls. This lustre is also much enhanced by their greater transparency, a really fine white, pink, yellow or iridescent pearl being translucent to a considerable degree.

### COLOR.

From a dead opaque white, the color is gradually enhanced to a beautiful iridescence, then, shaded with pink, yellow and salmon

examined, together with the localities where the pearls are found, and an account of such secretions as have commercial value though they are not properly pearls. The sizes, number of pearls and value of the annual yields will be noted as far as possible. Any information to assist in this work will be duly acknowledged in the forthcoming paper.

[2] W. H. Dall, Pearl and Pearl Fisheries, Amer. Naturalist, June–July, 1883.

tint, the color passes into a decided form of these colors; then faintly purple tinted passes into a bright copper red, so closely resembling a drop of molten copper as to deceive the eye. Some are a very light green and brown, others rose, pale steel-blue and russet brown. Purplish brown colors are not uncommon, and they are all, at times, beautified by a splendid lustre and iridescence.

FORM.

Some of the odd forms are very remarkable: elongated fish forms are quite abundant and with very little addition of gold and enamel they will represent fishes, human and dogs' heads, bats' wings, birds' wings. Mallet-shaped ones of fine color and lustre at each end are found; but as a rule with opaque sides. Bunched or grouped masses of the pearly nacre, are made up of from one to over one hundred distinct pearls, and and are of remarkable and fanciful shapes. These distortions are generally found under the mantle near the lip of the shell. Feather-like forms with curiously raised pittings, and an odd rounded variety with raised pitted markings, are quite abundant. One pearl, when mounted, strikingly resembled the bust of Michael Angelo, and some fine designs have been made of these baroques in the style of those mounted by Dinglinger at the Dresden Green Vaults. Although the pearls are not as large as the latter, more taste has been used in mounting them, and the variety of form being inconceivable it gives an artist in this line a wide field for imagination and design. Their value, however, is very trifling unless remarkably beautiful and lustrous. From one to one hundred pearls may be found in a single shell but such, as a rule, have little or no value. Very curious nacreous groups made up of many small pieces are at times found attached to the hinge. These are generally so lustreless as to be of little value and are rarely collected. These groups are caused by the conglomeration of many small ones, cemented by a pearly nacre, and are frequently half an inch across.

Of the Unio pearls not one in a hundred is of good shape, and probably not more than one in a hundred of these is really a fine pearl; and as the value of a pearl depends on lustre and form, not more than one pearl in a hundred is of more than trifling value. Rev. Dr. Hovey communicated to me that he had himself found a fine

pearl nearly one-half of an inch across in the shell of *Unio ovatus* at Cincinnati, O. Some of the pearls are opaque and apparently worthless, but if the outer layer of these chances to be thick, the pearly layer immediately underlying it may be clear and iridescent to some depth. In these cases the pearl may be made valuable by removing the outer coat with a weak acid solution. Sometimes the layer is not thick and restoration vain, for some pearls are not *pearly* throughout.

Unio pearls have often been found in the mounds of the Ohio Valley and the South, and some years since I was informed of a find near Cincinnati of some of these dead pearls one inch in diameter and quite round. Strange to say, after making inquiries I am unable to learn the possessor, although the find was really authentic. The greatest find, however, is one from the mound in the little Miami Valley explored by our Secretary, Prof. F. W. Putnam, and Dr. C. L. Metz, who procured over sixty thousand pearls, drilled and undrilled, undoubtedly of unio origin, all, however were, either decayed or very much altered, and of no commercial value.

Col. Chas. C. Jones, Jr.,[3] expatiates on pearl-finding in the southern mounds, and, in addition to his own valuable observations, gives exhaustive references to the early explorers.

Unio pearls have always been found since the early settlement of this country, but the finding at Notch Brook near Paterson, N. J., by Mr. Quackenboss of a pearl weighing ninety-three grains, of fine lustre, and sold by Tiffany & Company for about $2500, in 1857,[4] created an excitement that started the search for pearls in many of the states, and the appended list will show the results produced by it. The unios at Notch Brook and elsewhere were gathered by the millions it is said, and destroyed, often with little or no result. One large round pearl weighing four hundred grains was destroyed by boiling the shell to open it at this time. Many of the brooks and rivers were then completely raked and scraped; among them the Oletangy, at Delaware, Ohio, and a number of streams near Columbus, often in a reckless manner, with very little apparent result. Within one year pearls were sent in from nearly every state and fully $15,000 worth of pearls were purchased

[3] Antiquities of the Southern Indians, New York, 1873.

[4] This pearl is supposed to belong now to the Empress Eugenia and would to-day be valued at from $10,000 to $12,000.

in 1857; in 1858 about $2000; in 1859 about $2000; in 1860 about $1500; from 1860 to 1863 only $1500. The excitement then abated until about 1868, but since then many of the Little Miami river pearls have been found.

Within the last four years the pearls have nearly all come in from a comparatively new district and this source is apparently on the increase. At first few pearls were found west of the Ohio, or rather, few were looked for, but gradually the line has extended and now Tennessee and Texas are the principal pearl states, but they are also sent north from Florida.

1857 TO 1863.

*Locality.*

| | |
|---|---|
| Haydenville, Mass. | Paterson, N. J. |
| Sunderville, Mass. | N. Haven, Ct. |
| Forestville, Ct. | Gilford Village, N. H. |
| Haverstraw, N. Y. | East Hampton, Mass. |
| Rocky Hill, Ct. | Canton, Ct. |
| Unity, Me. | Waterbury, Vt. |
| Vermont. | Cincinnati, O. |
| Springfield, Mass. | Waynesville, Ohio. |

LARGE PEARLS.

| | | | | |
|---|---|---|---|---|
| 1857. | 1 | pearl | 93 | grains. |
| | 1 | " pink | 15 | " |
| | 1 | " " | 25½ | " |
| | 1 | " white | 40½ | " |
| | 1 | " round | 24½ | " |
| | 1 | " white | 25¾ | " |
| | 1 | " oblong | 24¾ | " |
| | 1 | " | 21 | " |
| | 1 | " oval leaden | 33¼ | " |
| | 1 | " pink | 31¾ | " |
| | 1 | " drop ribbed | 43½ | " |
| | 1 | " | 17¾ | " |
| | 1 | " | 21½ | " |
| | 1 | " white perfect | 31¾ | " |
| | 1 | " pear shaped | 19 | " |

| | | | | |
|---|---|---|---|---|
| 1857. | 1 | pearl | pear shaped, uneven | 60 grains. |
| | 1 | " | pinkish | 100 " |
| 1858. | 1 | " | perfect | 41 " |
| | 1 | " | | 38 " |
| 1859. | 1 | " | round | 13 " |
| | 1 | " | pink | 29½ " |
| | 7 | " | 15¼ to 29½ | " |
| 1860. | 2 | " | mated | 40½ " |
| | 1 | " | | 29 " |
| | 1 | " | perfect | 17 " |
| | 9 | " | 10½ to 19½ | " |
| 1863. | 1 | " | perfect | 39½ " |

PRODUCTION.

Sept., 1881 to 1882. 210 lots for $7500.
Sept., 1882 to 1883. 72 lots for $5000.
Sept., 1883 to August, 1884. 71 lots for $5000.

Single pearls, one from Montpelier, Vt., for $300; Waynesville, Ohio, for $200; Boston, Texas, for $250; one pink pearl, 19½ grains, from Murfreesboro, Tenn., for $80; another from Murfreesboro, Tenn., for $150; one from Llano, Tex., for $95.

The wholesale destruction and the changes in the water due to manufacturing industries have no doubt nearly exhausted many varieties of the Unionida.

Within the last five years, as the table will show, the pearls have been found principally in Tennessee, Texas and Kentucky. The more eastern states are so densely populated and the brooks so polluted with sewerage and refuse from factories, etc., that the animal life of the streams is exterminated or on the wane, in many localities. Vermont, New Jersey, and Ohio, where pearls were formerly found, have successively lost this resource, until, at present, very few pearls are obtained in these states.

One of the finest and best known collections of unio pearls is the one belonging to Mr. Israel H. Harris of Waynesville, O., who has for many years purchased and collected everything of value in his section of the state of Ohio, where some of the finest American pearls have been found. He has a large variety of all the oddities and also a fine lot of the good pearls.

### CONCH PEARLS.

The concretions found in the *Strombus gigas* are very beautiful, but since not nacreous, they are not true pearls. They are almost always pink in color and at times resemble rounded or elongated masses of the shell, but as a rule the fine ones are beautifully lustrous. They are rarely round, usually a little elongated or oblong in form, and the surface of the greater number is much beautified by the reflections produced by a fibrous stellated structure that causes the light to play over the surface, but in a manner different from satin spar or the cat's eye effect, owing to the different arrangement of the structures.

Mr. James R. Curry of Key West, Florida, states that at Key West and Tortugas fully 15,000 shells are used annually as an article of food, and also for bait, selling at the rate of three for ten cents, uncleaned. He has lately paid some attention to pearl collecting and never observed more than one in a shell. He instances one as large as a small hazel nut. A few of those found were of very fine color, equal to and some really finer in color than those from the West Indies, although not so regular in form. The principal colors were canary, salmon-pink, pink, black and pure white. The value of none exceeded $50. Pearls of this kind are obtained from the West Indies, some of which are worth $500 apiece. They have occasionally been observed one-half of an inch in length and of a very fine quality.

Of late years in the United States the demand has been somewhat limited. A $4000 necklace of these, in the possession of Messrs. Tiffany & Co., is worthy of mention. For some time they nearly controlled this whole fishery, but the yield is very uncertain. On the Pacific coast several species of Haliotis (abalone shell) are used by the Chinamen for food and bait. They secrete very curious pearly masses, sometimes with fine lustre, and choice enough to deserve a place among pearls. One of these measured two inches in length and one-fourth to one-half inch in width. A necklace of the fairest of them has been made by a California jeweller. A pearl over one-half an inch long and of good color, which was used as the body of a jewelled fly, cost $30. Mr. C. R. Orcutt of San Diego, Cal., has paid some attention to collecting these pearls.

The common clam (*Venus mercenaria*) at times secretes pearls.

These vary in color from a pure ivory white—so similar to an ivory button as to pass readily for it—to the same color, faintly tinted blue, and then passing from a reddish purple and a purple blue to nearly purple black. The white are valueless, the tinted of very little value, the darker colored pearls are often from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in diameter, and fine ones have retailed for $20 to $100. The writer has never known one to sell for more than $100. There is very little demand for them, and the supply is limited. Unless the color is very good they possess little beauty because they lack the lustre peculiar to other pearls, and as a rule are used as some part of a design. Mounting with diamonds very much improves the appearance of the darker ones.

Our common oysters (*Ostrea borealis and Ostrea Virginiana*) occasionally secrete one or more pearly bodies, always dead white in color. In addition to the form, there are, as a rule, brilliant reflections produced by a fibrous radiated structure, similar to that observed in the common conch. The "skin" of these pearls is never smooth or lustrous and consequently they have no value whatever, although often supposed to have. Rev. Dr. Hovey communicated to me that he had found twenty-nine pearls in a single common oyster (*Ostrea borealis*) at New Haven, Conn. In the Smithsonian report for 1881, page 131, Mr. Samuel Akron affirms that Mr. Chas. E. Ash took forty-five pearls from a single oyster in Providence Bay.

The reason so few American conchologists have paid attention to the American pearls is that it is really the old distorted and diseased shells that contain them, and for collections these are not as desirable as the finer shells. A number of these collectors who have opened many thousands of unios, have never observed a pearl of any value. The pearls are found either by farmers who devote only their spare time to this industry and if no result is obtained feel that there is no loss, or by those who have no regular pursuit and generally constitute the nautical element of our country villages. No doubt many shells are destroyed in this way that do not contain a pearl. There are young and old shells, those that have a pearly lining and those without, in the latter case the pearls are valueless. In order to obviate this wholesale destruction it would be well to use such instruments as have been employed in Saxony and Bavaria,—a thin, flat, iron tool with a bent end, in the former country. The end is inserted in the shell

and the handle then turned 90°, thus opening the shell without injury to the animal. Another implement is a pair of pliers with sharp-pointed jaws and a screw between the arms, which is turned by the hand until the valves of the shell are sufficiently distended to see whether it contains a pearl. If it does not the animal is returned to its former haunts, perhaps to propagate more valuable progeny.

I would suggest that, in gathering the shells, only such as are full grown, old, and distorted by disease be taken, that the fisheries may be preserved; and that the shells be opened as soon as taken from the water and not allowed to open by decay, since this discolors the pearls; and, particularly, that they never be opened by boiling, since this destroys all the lustre and value.

Perhaps the greatest pearl fishery in America is the one at La Paz, Lower California; most of these pearls are sent to market by way of San Francisco, and the total product of the fisheries has amounted to $250,000 per annum, and the sale of shells to as much more. The pearls vary in color from pure white, through all the shades of white, gray and brown, to black; the latter having become so fashionable of late years that their value has increased as much as ten-fold. The shell is the true pearl oyster (*Avicula margaritifera*). One black pearl, weighing fifty grains, was valued at $8000 by Messrs. Tiffany & Co. More will be said of this fishery in a subsequent paper.

| | *Locality.* | *No. of Pearls.* | *Weight.* | *Paid.* | |
|---|---|---|---|---|---|
| Nov. 1868 | LaPaz | 1 dark | 22¼ grs. | | |
| | " | 149 | 321¼ " | | |
| | " | 164 small | 444⅜ " | | |
| | " | 5 dark | 47½ " | $945.00 | gold |
| | " | 1 white | 28½ " | | |
| | " | 18 dark pear | 8¾ to 45¾ grs. | | |
| | " | 10 white pear | 8 to 28½ grs. | | |
| | " | 1 | 26½ grs. | 10.00 | " |
| | " | 1 | 23½ " | 9.00 | " |
| | " | 1 | 17⅝ " | 5.50 | " |
| | " | 30 large | lot of small | 985.30 | " |
| | " | 396 | 331⅜ carats | 2300.00 | |
| | " | 57 | 159⅛ " | 823.00 | |
| Jan. 1869 | " | 2 | 21½ " | 322.50 | |

| | *Locality.* | *No. of Pearls.* | *Weight.* | *Paid.* | |
|---|---|---|---|---|---|
| Jan. 1869. | LaPaz | lot | 1½ oz. | 60.00 | |
| | " | 17 | 36 carats | 100.00 | gold |
| | " | lot small | 151 carats | 62.50 | |
| | " | 12 black | 400 grs. | | gold |
| | " | 243 | 6615 " | 7000.00 | |
| | " | lot small | 2 oz. | | |
| | " | 1 white pear | 11⅜ carats | 195.00 | " |
| | " | 1 white acorn | 5 1/16 " | 45.00 | " |
| | " | 1 gray | 12¾ | 175.00 | " |
| | " | 60 white and black | 128½ carats | 514.00 | " |
| Feb. | " | 4 lots | 5424 grs. | 5200.00 | " |
| April. | " | lot | 1160 23/32 carats | 770.56 | " |
| | " | 193 | 351 15/16 cars. | 1425.00 | " |
| Sept. 1869. | " | 1 | 49 grs. | 294.00 | " |
| | " | 3 lots | 8¼ oz. | 795.00 | " |
| | " | 268 | 2335 grs. | 4136.00 | |

## TITLES OF OTHER PAPERS READ IN SECTION I.

THE AIMS AND METHODS OF MANUAL TRAINING SCHOOLS. By Prof. C. M. WOODWARD, Washington University, St. Louis, Mo.

THE EDUCATION OF PAUPER CHILDREN INDUSTRIALLY AND OTHERWISE. By Rev. JAMES O. BEVAN, Edgebaston, Birmington, England.

THE PHILOSOPHY OF CRIMINAL DEVELOPMENT. By Prof. LEWIS M. HAUPT, University of Penn., Philadelphia, Pa.

ON INDEXING THE LITERATURE OF SCIENCE. By B. PICKMAN MANN, Department of Agriculture, Washington, D. C.

THE PRINCIPLES OF GRAPHIC ILLUSTRATIONS. By Dr. FRANKLIN B. HOUGH, Lowville, N. Y.

PRODUCTION AND DISTRIBUTION. By EDWARD ATKINSON, Boston, Mass.

EXPERIMENTS IN A NEW METHOD OF LAND CULTIVATION BY THE USE OF DYNAMITE AND THE IMPORTANT RESULTS OBTAINED. By GEO. W. HOLLEY, Ithaca, N. Y.

A NATURAL SCHEME OF HIGH CULTURE. By KNUT FORSBERG, New York, N. Y.

A NEW RESOURCE FOR THE WOMEN OF THE UNITED STATES: SILK CULTURE. By LORIN BLODGET, Philadelphia, Pa.

BRIEF OUTLINES OF THE INVESTIGATIONS UPON THE POWER TO MOVE RAILROAD TRAINS, AND THE MECHANICAL INSPECTION OF RAILROAD TRACKS, AS MADE BY THE DYNAGRAPH AND TRACK INSPECTION CAR. By P. H. DUDLEY, New York, N. Y.

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The following title of a paper was accidentally omitted from

## SECTION A.

MECHANICAL ARITHMETIC, ILLUSTRATED BY THE AVERAGING MACHINE. By W. S. AUCHINCLOSS, Philadelphia, Pa.

## ABSTRACT OF THE PROCEEDINGS OF THE ENTOMOLOGICAL CLUB OF THE A. A. A. S.[1]

THE meetings of the Club were very well attended, some thirty gentlemen and ladies having been present; among them some of our best known entomologists. A feature of the meeting was the presence of Dr. Jno. G. Morris well known to all entomologists as one of the pioneers in American Lepidopterology; to whom we owe our first catalogue, and to whose efforts we owe also the first attempt at systematizing our lepidopterous fauna. It will no doubt be a pleasure to our readers to learn that Dr. Morris has announced his intention of returning to his first love — Entomology, and we doubt not he will be hailed with sincere pleasure by the new generation of entomologists who have hitherto known him so favorably by what he has already done.

Sept. 3d. Officers elected. John G. Morris of Baltimore, President; Herbert Osborn of Ames, Ia., Vice-President; John B. Smith of Brooklyn, Secretary.

Dr. Horn called attention to the historical associations connected with the place in which the club then met. On that very spot in the old Museum of Natural History, Thomas Say, poor in pocket, though rich in brain, put up his bed under the skeleton of some large mammal, and this for months was his only home. There also he contracted the illness which resulted in his death.

A paper from D. S. Kellicott, "On the ovipositing apparatus of *Nonagria subcarnea*" was read by the Secretary.

The last two abdominal segments of the ♀ are strangely modified. The last is laterally broad, chitinous except at base, terminating in two finger like processes; these are connected at the apices and curve downward. Two concave discs lead to the anal orifice; it is evidently along this channel that the eggs are passed by the ovipositor. On either side, and below the groove is a strong chitinous ridge with saw-like teeth, pointed backward. The other modified ring consists of a heavy band with stout posterior processes for muscular attachment; below are two stout chisels pointing backward and overlapping the first basal teeth of the "saws" of the last ring.

The eggs are laid near the edge of the leaf in a row, and the leaf is then bent over the eggs, carefully cemented down, and a perfect tube thus formed. The manner in which this is done has not been witnessed.

The imago has a very peculiar and very prominent pointed clypeal projection, of use probably in enabling it to pierce the stems of the *Typha* in which it lives during the larval period and undergoes its transformation.

[1] Printed at the request of the Club.

Mr. Smith cited the presence of similar modifications in other groups of the Noctuidæ.

Mr. John B. Smith exhibited six large photographic plates of *Agrotis* and gave a review of the remarkable range of variation in structure found in the genus, much greater than in many recognized genera.

In response to a question from Dr. Morris, Mr. Smith said that in the *Noctuidae*, genera were undoubtedly based upon very thin characters — less so than in *Coleoptera*, however.

Dr. Horn said it was long since laid down by Lacordaire that characters of scarcely specific value in one group formed excellent bases for high divisions in others; genera have no existence in nature and are created only for convenience in dividing up large masses of species to facilitate recognition. Nature has species only. Of late, however, persons afflicted with the *mihi* itch, finding new species scarce had taken to describing genera. For 12,000 species of *Coleoptera* some 2000 genera had been described.

Dr. McCook said in the spiders and ants there is plenty of room for persons with the *mihi* itch, as there is a very large mass of undescribed material.

Mr. B. P. Mann then proposed a combination of the entomological journals of America to be published by a stock company and to combine the good features of each. This proposition provoked much discussion and while the general sentiment was in favor of such a publication the opinions also went generally to the point that it would be still less likely to pay than those now existing. The Am. Entom. Soc. is wealthy enough to publish everything in the way of long systematic papers presented to it, and the "Transactions" would be the natural avenue for such works. The Bull. Bkln. Ent. Soc. covered another ground in the way of reducing to its simplest and most comprehensive form the knowledge of Coleoptera and Lepidoptera: often, as Dr. Horn stated, publishing the result of two weeks' hard work, on less than two pages. It was also published and supported by a Society willing and able to support it. The Can. Ent. was supported by government aid. "Papilio" was established merely to enable certain authors to get into print more rapidly than they could otherwise do, and its editor announced that he saw no reason for its continued existence. "Psyche" has a hard struggle, but will not suspend just yet.

A committee was appointed to consider whether such a combination was advisable, and whether and how it could be supported.

This committee afterward reported adversely to any such scheme.

Prof. Fernald then proposed a series of very interesting questions provoking considerable discussion, and on these questions he would like the opinions of all who may have considered them.

1. Where a name has once been published by an author, shall we change the mode of spelling to one more consistent with its derivation; *e. g.:* Treitschke writes *Cochylis*, probably by mistake; shall we adopt his spelling or the more correct *Conchylis*?

Dr. Horn said no: some authors merely put together a lot of letters without any meaning whatever and called them names of genera. If such barbarisms were accepted we should not change a name as originally spelled by the author. Mr. Mann agreed with Dr. Horn. Dr. McCook thought we might make the change; but not if thereby the author's right to priority would be destroyed.

2. Where an author publishes a name manifestly incorrect in orthography, and in a later work corrects his own error, shall we adopt his correction?

The sentiment was that when the correction was made within a reasonable time and before the incorrect form had come into general use, it should be adopted.

3. Should the termination of the specific name be made to agree with the generic in gender? *e. g.*, Zeller writes *Tortrix viridana; Exartema permundanum; Lophoderus ministranus.* Shall this rule be adopted, or shall we adopt the ending in *ana* irrespective of the gender of the genus?

Dr. Horn said in Coleoptera specific and generic names always agree in gender; where, however, a termination means something; *i. e.*, indicates the family to which an insect belongs, he would use the uniform terminations. Mr. Mann said he did not believe in uniform terminations and while he would not change existing names, neither would he consider himself bound to uniform terminations in proposing new ones.

4. Where a *Tortricid* species is described with a name not ending in *ana* should this be changed to *ana*? *e. g.*, *Carpocapsa pomonella*? Prof. Fernald said he was adverse to such change, and no one disagreed with him.

5. To what extent should the law of priority be made use of? Shall we make use of the oldest name even if the species has been known under another for a long time? If not, for how long a time must a name universally or generally be in use to take precedence over an older name?

The sentiment of the meeting was that discussion of this question would be useless, as no conclusion, even if one were reached, would be respected.

6. What should be taken as the starting point in nomenclature; some have taken the 12th edition of Lin. Syst. Nat. while others have taken the 10th edition?

No decided opinions were elicited though preferences were stated.

Prof. Fernald expressed surprise that Hübner's Verzeichniss genera should be so generally ignored, though they were after a fashion described, while Guenee's genera of micros proposed in the Index methodicus, though not sanctioned by one word of description were universally adopted.

Dr. Horn thought the case might be parallel to that of Erichson and Motschulsky both of whom had proposed some generic terms without description; but while Erichson's genera were all adopted because they always were well founded, Motschulsky's were as uniformly ignored because usually unfounded.

Mr. Smith said as to *Noctuidae* the parallel would hold. Prof. Fernald

said, not so of *Tortricidae;* Guenee has just as many baseless genera as Hübner has.

Sept 4th—On this occasion the meeting was held at the Ac. of N. Sc. in the rooms of the Am. Ent. Soc. Mr. J. H. Emerton exhibited a large number of his types of spiders recently described by him, and the collections of the Society were open.

Mr. Smith gave an account of the secondary sexual characters of some Lepidoptera, notably *Noctuidae* and *Deltoidae*, illustrated by blackboard sketches. In the *Deltoids* these characters are most aberrant; in the *Herminiinae* the anterior coxa is slender, much elongated, the femur a mere shell, furnished with a dense tuft of long hair; the tibia is more or less aborted, and modified into a flattened plate, also furnished with a large tuft. The first tarsal joint which is usually mistaken for the tibia is greatly elongated and is inserted into the tibia near the base. In *Palthis* the tibia is very short, and the tarsi developed to an enormous extent. In addition the ♂ *Palthis* has a very long tuft of hair on the terminal joint of palpi. Various antennal peculiarities were noted, *Renia* has a strongly bent joint at basal third, from the base of which proceeds an articulated appendage fringed with hair. *Zanclognatha* has a different bend and lacks the articulated appendage. The modification in the ♂ of *Heliothis paradoxus* and other forms with pellucid spots on primaries was discussed, and the questions raised: What purpose do they serve? What value shall they have in classification?

Prof. Fernald said in the *Tortricidae*, generic and even higher value had been accorded these characters. A prominent one in this family was the costal fold which sometimes extends two-thirds across the wing.

Dr. Horn said both sexes must be considered in characterizing a species; a species consists of two separate individuals which must be studied as one. Synoptic work has a higher aim than the mere recognition of species.

Mr. Macloskie called attention to some sexual differences in birds; the flickers of the East and West were widely different: in intermediate points intermediate forms were found and the ♀s were almost indistinguishable. Yet they were distinct, and though no anatomical differences could be found there must be a physiological difference.

Mr. Osborn read a paper on *Mallophaga* and *Pediculidae*, calling attention to the correspondence of identical or very similar species on the closely related birds and mammals of Europe and America, citing a large number of instances.

Miss Cora H. Clarke gave an account of the habits of some Caddis fly larvæ belonging to *Hydropsyche* and *Plectrocnemia*, exhibiting specimens of their work.

Mr. Mann explained how Prof. Barnard raised larva living in running water; he confined them in a glass tube, one end closed by a porous substance, the other fastened to a faucet. In this way a steady flow of water of any desired strength can be kept up.

Dr. Morris exhibited a gall recently collected and asked information

concerning its identity. Asked also what orders of insects are known to produce galls. Mr. Osborn said about all orders except *Orthoptera* and *Neuroptera*. Mr. Smith said at last one American *Apionid* was known as a true gall producer, while several European species formed root galls.

Mr. Mann said in bibliographical work he had found great difficulty in indexing galls; he had among others indexed them under descriptive botany.

Mr. Osborn said while many plants, especially the *Rosacea*, were subject to galls yet they were produced by insects and are abnormal so far as the plants are concerned; almost every species of insect produces a peculiar gall of its own.

Dr. Hoy said galls were pathological appearances and rather diseases of plants; as much out of place in descriptive botany as a description of cancer in a description of the lips.

Dr. Morris remarked on the scarcity of larva and imagines of Lepidoptera, which produced much discussion, and showed that while northward there had been no unusual dearth of insects, elsewhere all insects had been remarkably rare. *Cardui* was an exception and generally common. Mr. Aaron cited a remark of Mr. Ridings that he was always afraid of a season when *cardui* was abundant, for then, usually, nothing else would be found.

Dr. Hoy remarked that in his locality (Racine, Wis.) he had found many insects usually more southern, and started a discussion upon the range of *P. turnus*.

The question then turned upon the food plants of *P. ajax*. Dr. Hoy said the pawpaw was not found within 200 miles of Racine, while *ajax* had often been found, still fresh and not fully developed.

Mr. Aaron gave spice wood and upland huckleberry as further food plants. Dr. Hoy said they had the huckleberry but not the spice bush at Racine.

Mr. Osborn had seen *ajax* but knew of neither huckleberry, pawpaw nor spice bush in the vicinity of Ames, Ia.; of the spice wood he was not sure —it might be there. He reports from Sioux City, that there *Chrysochus auratus* is so common that it is crushed under foot in the streets. Mr. Mann has seen them in woods in piles upon stones.

Mr. Saunders reported an abundance of *H. textor* everywhere through Canada, and from West Canada an invasion of the larva of *Grapta progne* on currants.

Mr. Græf exhibited some specimens of Lepidoptera, rare or typical, of recently described forms.

Sept. 8th.—Prof. Martin exhibited some specimens of gum copal containing imbedded insects, all of which appeared to be of a post tertiary type. The gum is obtained near the equator, some distance from the shore, by digging at the site of old forests, long since extinct, the gum being the product of such trees. Among the Coleoptera, Dr. Horn recognized a form allied to *Callida*, 2 *Chrysomelids*, 1 *Clerus*, 1 *Cymatodera*, 2 *Longicorns* near *Clytus* and *Leptura* and an Elaterid much like one of our

species of *Cardiophorus*. Mr. Smith recognized one of the *Lepidoptera* as a *Mamestra*, and the *Hemiptera* as representing common living types, one homopterous species remarkably like a form now common, and in the *Diptera* a common *Muscid* type.

Prof. Lintner gave the results of some observations on injurious insects. *Orgyia leucostigma* was very rare in Albany. Mr. Dimmock found the same in Boston. Mr. Hulst the same on L. I., and Mr. Smith the exact contrary at Cape Cod, Mass.

From Michigan the larva of *Agrotis fennica* is reported as so abundant that it is called the black army worm. Usually this is a rare insect. *Podisus cynica* has been observed destroying the currant worm in numbers. *Lygus linearis* is injurious to green peas, stinging and blotching them. *Poecilocapsus lineatus* has seriously injured gooseberries, stinging the branches and thus causing their death.

*Phytonomus punctatus* has spread westward and attacked beans; a new habit for this insect. *Crioceris asparagi* has moved west as far as Geneva, N. J.; heretofore it has been confined to the coast districts. *Galerucella xanthomelaena* has been very destructive to elms. A vast number of specimens of *Otiorhynchus ligneus* were found in a house which had been closed for four years. What had they fed on? There was nothing in the house, and one of the natural articles of food is the strawberry root.

A curious seed (*Euphorbia*, probably) from Mexico was exhibited locally known as the "jumping seeds." The peculiarity consists of a series of erratic movements and leaps made by the apparently perfect seed. They contain, however, a larva of *Carpocapsa saltitans*, and it is the motions of this insect which cause the movements of the seeds; why they make these motions is unknown. The species closely resembles *C. pomonella* but has very differently formed legs, the tarsi being hidden by long scaly tufts.

Dr. Horn calls attention to the fact that all the injurious Coleoptera cited by Mr. Lintner were imported species and that the fact of their motion westward along the line of their food plant was to be expected. *Crioceris* 12-*punctata*, also an imported species, has been taken near Baltimore; near that city, and Alexandria many imported species are found. *Blaps mortisiga* and one other species are common; the former can be taken in some places by the bushel. The remarkable increase of some species is curious. In 1874 when working with Dr. Leconte on the *Rhynchophora* among all their material only a single specimen of *Aramiges Fulleri* was contained and that came from Montana. A year or two after it was received from all parts of the country and was dreaded as one of the worst hot house pests. How did this species spread so suddenly over so large a territory? Prof. Lintner had first found the insect in 1876. Mr. Dimmock finds it very troublesome in hot houses, particularly on roses. Mr. Hulst noted the appearance in large numbers of a downy insect on maple. Mr. Lintner said it was *Coccus* (*Pulvinaria innumerabilis*). Prof. Osborn had noticed the same insect, and gave its life history. No less than seven species of insects are known to prey on it. Mr. Saunders has

noticed it, and the larva of *Chilocorus bivulnerus* also had been so common as to attract attention and cause alarm. Mr. Underwood reported that the species is said occasionally to attack the elm.

Dr. Horn gave an account of secondary sexual characters of coleoptera comparative with Mr. Smith's account of Lepidoptera. In *Collops* the antennal modification is very like that of *Renia*, and the use of it has been observed: the ♀ antenna is grasped in the bend of that of the ♂; the articulated appendage is thrown forward, and the antenna beyond the bent joint is thrown backward, so that during copulation the ♀ is firmly held. In *Meloe* is a structure very similar to that of *Herminia* and answering a similar purpose. The palpi in *Sphalera* (*Tomoxia*) sometimes have an articulated appendage near the tip, probably also serving as a grasping organ. These organs are explainable. Other modifications are obscure. *Lebia* for instance has a notch at the inner side of the middle tibia near tip; a species of *Aphodius* has a very curious hook to the first joint of hind tarsi; another has a peculiar clavate appendage to the inner side of fore tibia near tip.

Mr. Cresson said, that except in the parasitic forms which he has not studied, the Hymenoptera show no such peculiarities.

Mr. Osborn said that in *Mallophagidæ*, and especially in *Lipeurus*, a modification of the antenna similar to that of the *Tomoxia* palpi was found, and also undoubtedly served as a clasping organ.

A committee of three was appointed to arrange a programme and obtain papers for the next meeting of the club, which then adjourned. Committee: J. B. Smith of Brooklyn, Chairman, and B. Pickman Mann of Washington, and Herbert Osborn of Ames, Iowa.

JOHN B. SMITH, *Secretary*.

## FOREIGN SOCIETIES REPRESENTED BY DELEGATES AS NAMED.

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ACCADEMIA DEI LINCEI, Rome, . . . . . Prof. J. D. Dana.
ORNITHOLOGISCHE VEREIN IN WIEN, . . . . . Dr. C. Hart Mérriam.
SOCIÉTÉ ENTOMOLOGIE DE BELGIQUE, . . . . . Dr. H. A. Hagen.

LINNEAN SOCIETY, . . . {Mr. John Ball, F.R.S.
Mr. A. W. Bennett, F.L.S.
Mr. W. Carruthers, F.R.S.
Vice Pres. Linnean Society.
Mr. De Laune, F.L.S.
Dr. James Murie.
Mr. Howard Saunders, Council Linnean Society.

BELFAST NATURAL HISTORY AND PHILOSOPHICAL SOCIETY, . . . . . {Mr. James Musgrave.
Mr. Henry Musgrave.

GEOLOGICAL SURVEY OF INDIA, Mr. Theodore Hughes Hughes, A.R.S.M., C.E., of the Imperial Museum, Calcutta, Deputy Supt. Geological Survey.

ROYAL ACADEMY OF LUCCA, {Hon. Theodore Lyman.
Prof. A. Graham Bell.

ASIATIC SOCIETY OF BENGAL, . . . . . W. T. Blanford, F.R.S.
SOCIÉTÉ ANTHROPOLOGIQUE DE BRUXELLES, . . . . . Dr. Victor Jacques.

ASSOCIATION FRANCAISE POUR L'AVANCEMENT DES SCIENCES, . . . . . {Prof. Joubert.
Prof. Silva.

ASIATIC SOCIETY OF JAPAN, {Dr. David Murray.
Rev. E. W. Syle, D.D.
Mr. Percival Lowell.

ROYAL MICROSCOPICAL SOCIETY, . . . . . {Rev. W. H. Dallinger, F.R.S., F.L.S.
A. W. Bennett, M.A., B.S., F.L.S.
James Glaisher, F.R.Sc., F.R.A.S.

ROYAL IRISH ACADEMY, . . . . . Prof. R. S. Ball, M. A., LL. D., F. R. S.

ROYAL GEOLOGICAL SOCIETY OF IRELAND, {Prof. Valentine Ball, M. A., F. R. S., F. G. S.
Prof. W. J. Sollas, M. A., F. R. S. E., F. G. S.

PHILOSOPHICAL SOCIETY OF GLASGOW, {H. Muirhead, M. D.
Prof. James Mactear.
J. G. McKendrick, M. D.
W. C. Crawford, M. A.
Mr. J. Kirson.

NATURAL HISTORY SOCIETY OF GLASGOW, . . . . . D. Corse Glen, F. G. S.
ROYAL BOTANICAL SOCIETY, . . . . . Mr. W. C. Crawford.
MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY, Prof. A. M. Marshall, M. A., M. D., D. Sc.

ROYAL SOCIETY, . . . . {Prof. Sir William Thompson, LL. D., F. R. S.
Dr. John Hopkinson, F. R. S.
W. H. Preece, C. E., F. R. S.
W. T. Blanford, F. R. S.
H. W. Moseley, M. A., F. R. S.

UNIVERSITY OF TOKIO, JAPAN, Prof. D. Kikuchi, Rigaku Bucho, Tokio, Daigaku. Dean of the Department of Science.
IMPERIAL SOCIETY OF FRIENDS OF NATURAL SCIENCE, ANTHROPOLOGY AND ETHNOGRAPHY OF MOSCOW . . . . . C. DE STRUVÉ.
ROYAL INSTITUTION OF GREAT BRITAIN, James Dewar, Fullerian Professor of Chemistry, M.A., F. R. S.

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| ROYAL ZOOLOGICAL SOCIETY OF IRELAND, | Robert S. Ball, LL.D., Astronomer Royal of Ireland.<br>Anthony Traill, M. D.<br>Henry M. Barton.<br>William E. Peebles. |
| ROYAL DUBLIN SOCIETY, | George Francis Fitzgerald, M. A., F. T. C. D., F. R. S.<br>Alfred Cort Haddon, M. A., F. Z. S. |
| BOTANICAL SOCIETY OF EDINBURGH, | Wm. Caldwell Crawford. |
| ZOOLOGICAL SOCIETY OF LONDON, | George E. Dobson.<br>Howard Saunders.<br>Philip Lutley Sclater. |
| NATURALISTS' CLUB OF ROCHESTER, ENG. | R. G. Hobbes. |
| GEOLOGICAL SURVEY, LONDON, | W. T. Blanford, F. R. S., Secretary. |
| STATISTICAL SOCIETY OF LONDON, | J. Biddulph Martin, M. A., F. S. S.<br>Major Patrick S. Craigie, F. S. S. |
| PERTHSHIRE SOCIETY OF NATURAL SCIENCE, PERTH, SCOTLAND. | R. Pullar, F. R. S. S.<br>R. D. Pullar, F. C. S. |
| YORKSHIRE GEOLOGICAL AND POLYTECHNIC SOCIETY.<br>CUMBERLAND AND WESTMORELAND ASSOCIATION FOR ADVANCEMENT OF SCIENCE AND LITERATURE,<br>CONCHOLOGICAL SOCIETY OF GREAT BRITAIN,<br>BARROW FIELD NATURALISTS SOCIETY AND SCIENTIFIC ASSOCIATION, | G. H. Parke, F. L. S., F. C. S. |
| NORFOLK AND NORWICH NATURALISTS SOCIETY, | Michael Beverley, M. D. |
| PHILOSOPHICAL SOCIETY OF ABERDEEN, | Prof. Struthers. M. M.,<br>Dr. Robert Beveridge. |
| THE SOCIETY OF ENGINEERS, LONDON, | Arthur Rigg, President. |

REPRESENTATIVE U. S. SIGNAL OFFICE, . . . . . Cleveland Abbe.

In response to the invitations of the Local Committee, letters of acknowledgment and regret were announced as received[1] from the following societies.

PHYSICO-MEDICAL SOCIETY OF ERLANGEN.
BOMBAY BRANCH OF THE ROYAL ASIATIC SOCIETY.
ECOLE NATIONALE DES MINES.
MINERALOGICAL SOCIETY OF GREAT BRITAIN.
GEOLOGICAL SOCIETY OF BELGIUM.
R. ISTITUTO VENETO DI SCIENZE, LETTERE ED ARTI.
ROYAL ASIATIC SOCIETY.
BELGIAN MICROSCOPICAL SOCIETY.
GERMAN ANTHROPOLOGICAL SOCIETY.
ACADEMIE DES SCIENCES, BELLES-LETTRES ET ARTS DE ROUEN.
ROYAL BAVARIAN ACADEMY OF SCIENCES.
BOTANICAL SOCIETY OF FRANCE.

[1]Just after the adjournment of the meeting, a letter was received from Sig. FLORENCIO L. DOINQUEZ, Secretary of Legation of the Argentine Republic, in Washington, stating he had been appointed to represent the Argentine Scientific Society of Buenos Ayres, but that his appointment was not received until the day after the adjournment of the association.

# EXECUTIVE PROCEEDINGS.

## REPORT OF THE GENERAL SECRETARY.

### THE THIRTY-THIRD ANNUAL MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

IN accordance with the action taken at the Minneapolis meeting in 1883, the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE met in GENERAL SESSION in the Academy of Music, in Philadelphia, at 10.30 A. M., on Thursday, Sept. 4, 1884; the retiring President, Prof. C. A. YOUNG, of Princeton, in the chair.

After a prayer by the Rev. Dr. MCCOOK, President YOUNG said: It is now my pleasure to surrender the post I have had the honor to fill for a year to the new President, Prof. J. P. LESLEY, of Philadelphia, to whom I extend a respectful greeting.

On taking the chair President LESLEY paid a compliment to the retiring officer and said: The large number of friends of science here assembled and the distinguished allies from foreign lands assure the unequivocal success of this meeting. Additional interest is vested in this annual session by reason of the coincident occurrence, during your stay here, of a great exhibition illustrative of an important branch of science. It is also doubly memorable, being held, as it is, in Philadelphia, the birthplace of American independence, the centre of civilization, literature and science — a city distinguished as the home of civil and religious liberty and a spot always famous for its intelligence and hospitality.

President LESLEY then introduced His Excellency Governor PATTISON, who extended a welcome to the visitors on behalf of the state of Pennsylvania in the following words:—

Mr. President, Ladies and Gentlemen:— Custom and propriety have led me here to-day to fill a pleasant part in the proceedings of your great assembly, to extend to you a sincere welcome in the name of the Commonwealth of Pennsylvania. I wish that your stay here may be pleasant, and your deliberations productive of good. As I look around upon this gathering of men devoted to the study of science and reflect from how many different parts of the country they have come, and that some have crossed the wide ocean, I am at once impressed that this is no ordinary assembly. Tacitus declares that in his day, men were hemmed in by mountains and fear. But since the advent of the spirit of science that condition has happily disappeared. "Old things have passed away; all things have become new." All parts of the world are now brought into a very close and reciprocal intimacy. The international feature of your congress, therefore, may not be so remarkable, but it is certainly exceedingly grateful to our feelings and should be inspiring to our hopes for the future.

Not alone to you who are dwellers on American soil, but to you, gentlemen, who come hither with fraternal greetings to your brethren, I beg leave to extend an assurance of cordial welcome and right hearty good will.

I think I place a proper value on this public occasion when I say that we Pennsylvanians feel a very deep interest in the objects of your meeting, for in no other state of the Union does there exist a closer relation between the livelihood of the people and practical science. Indeed, you could not have selected, in my humble judgment, a more fitting place for your congress to meet.

One hundred and nineteen years ago, Robert Fulton was born in Lancaster county, in this State. He began life as a portrait painter, without friends or fortune; but, by his successful labors in perfecting steam navigation, he has made himself one of the greatest benefactors of mankind. Through his labors the very geography of the civilized world has been changed. The seas have been bridged. Time and space have been partially annihilated. New highways have been opened. The wilderness has been redeemed. Distant states have been neighbored. Deserted villages have been changed into flourishing cities, and skilled labor has been elevated.

The imagination is baffled by the present triumphs of steam, and vainly attempts to anticipate those of the future.

Here, too, lived that wonderful man, Benjamin Franklin, whose honored dust quietly reposes in its sepulchre not far from the place where you are assembled. It is true that a hundred years before his day the electric fluid was known to science, but it was left to him to institute an experiment by which it was demonstrated that lightning is an electrical appearance.

If we could boast of no other record than this in connection with science, it would be sufficient, I am sure, to commend us to the respect of the scientific world.

But Pennsylvania has reason to boast of other great souls, whose toils, if less known, are none the less valuable. In all the practical avenues of multifarious industry, their footprints are distinctly seen. To them we are indebted for much of the success attending the development of our marvellous resources as a state. Wherever a mine has been opened, a furnace set in operation, or a factory started on its humming career, the busy fingers of science have found employment. The principles which regulate the operations of the mechanical powers, and which lie at the foundation of complicated machinery, which relate to the smelting and refining of metals, the composition and improvement of soils, the reduction and uniform whiteness of vegetable fibre, the mixture and application of colors, the motion and pressure of fluids, the property of light and heat, the navigation of rivers and seas, and the laws of magnetism, electricity and galvanism, may all be seen illustrated among the thousands of industrial establishments which punctuate this great state from side to side.

There is now in course of erection in the splendid bay of New York, a gigantic pedestal, on which is to stand Bartholdi's famous statue of "Liberty enlightening the World."

It has seemed to me that that already renowned work of art symbolizes the aim of your congress. For if I rightly apprehend it, it is to disenthral where there is bondage. It falls to the high lot of science to eradicate many errors, and to pursue to their principle many accidental improvements in the processes of industry. The useful, like the ornamental arts of life, are to be carried to the point of perfection.

This is the mission of science in every department of thought, genius, and industry, and your utterances here in the discussion of various questions that lie directly within this circle may go far towards enlightening mankind on points around which there is much darkness to-day.

Pardon me, gentlemen, if I venture a word just here as to the value of a thought. It has been said that the great men of the earth are shadowy men, who, having lived and died, now live again and forever through their undying thoughts. Thus living, though their footprints are heard no more, their voices are more than the sound of many ages, and unceasing as the tides of air. Thus it is, that they live to-day, who long ago startled the world of science with some mighty thought in which lay concealed incalculable good to mankind. Only a thought—yet a thought that has led to wonderful results.

The falling of an apple — a very commonplace incident — gave rise to the one germinal thought that led Sir Isaac Newton to work out his system of the universe. Columbus conceived the mere idea of a western continent, but his wildest vision of the consequences of such a discovery could not have embraced in the remotest degree the great changes in the political, commercial, and social condition of man which it has really brought about. Only a thought led to the invention of printing, to the application of steam to practical uses, to the adaptation of electricity to illuminating purposes, and to a thousand other discoveries which are blessing the world to-day. Brilliant as are the achievements of science, they are destined to be outstripped in the future through the new-born thought that may, to-day, drop into the soil of human affairs, and, like good seed, spring forth in beauty and strength. Thought and science go hand in hand. The properties of matter are not all discovered, nor its laws all found out, nor the uses to which they may be applied all detected. There are treasuries of truths in reserve to reward the patience and labors of the faithful scientist.

On the great northeast coast of the Pacific ocean is a vast chasm formed by the torrent of the Columbia rushing between Mt. Hood and Mt. St. Helen's. It breaks through the ridges of the Cascade mountains to find the sea. The visitor stands in amazement as he hears his slightest tone repeated and re-echoed with a larger utterance in reverberations, that lose themselves at last amid the surrounding hills. So, gentlemen, standing here in this congress, and speaking in the name of science, your words will be caught up and borne away in reverberations that may roll

around the globe itself. May it be that in the dissemination of the earnest thought of your great body the welfare and happiness of mankind shall be the fruitage.

Mr. President and gentlemen, again I extend to you, one and all, a sincere and cordial welcome.

His Honor WILLIAM B. SMITH, Mayor of Philadelphia, was next introduced by the President, and in a brief speech said that after the hearty words of welcome which had been extended by the Governor of the Commonwealth, it remained for him simply to add that the municipality of Philadelphia, a city within whose limits there were as many happy homes as any city on the civilized globe, and abounding with institutions of education, of philanthropy and of religion; there is a chord of sympathy and greeting which needs no expression at my hands.

Whatever can be done to make your sojourn pleasant, or to add to your comfort and convenience will find a ready response in the hearts of our citizens. I sincerely hope that your labors and considerations may be abundantly successful, and that upon your departure from the city you may be able to say, that here were found a people loyal to their country, creditable to the spirit of humanity and enjoying the blessings of Providence whose goodness reigned over them.

To the above addresses of welcome President LESLEY responded as follows:

This welcome is like that of a parent to a returning son. This Association was virtually born in Philadelphia. About the year 1832 was organized the Society of Geologists of Pennsylvania. It held meetings in this city regularly, and the result was that in 1840, eighteen of the principal geologists of the eastern part of the United States met on April 2, in the Franklin Institute, and organized the Association of American Geologists and Naturalists.

In 1841 they held their second annual meeting, and the next year their third, in Boston. In 1847, so many astronomers, mathematicians and other men of science had entered the charmed circle of this Association that it was necessary to change its name to signify the enlargement of its scope. In the year 1848 the first meeting of the American Association for the Advancement of Science was held in Philadelphia, and since then the Association has held its yearly sessions in all the principal cities of the Union. It now comes back to its home — Philadelphia.

President LESLEY announced that by direction of the Standing Committee he had sent a congratulatory dispatch by cable to the French Society for the Advancement of Science, that had opened a congress in Blois yesterday about an hour before the beginning of the convention here. He added, with a smile, that the Gallic Society had been a little more quickly courteous than the American and had cabled a greeting that arrived before the message of his own Association had been put on the wires. The French society's dispatch being translated read:

"The French Association for the Advancement of Science, collected in congress, addresses to her American sister wishes for prosperity and compliments friendly and confraternal."

An invitation was read from the President of the Electrical Exhibition, inviting the Association to visit the exhibition in a body. It was announced that the Standing Committee had accepted the invitation for September 10. A similar invitation was accepted from the United States Coast and Geodetic Survey, though no day was set for a visit.

A touching letter was read from Dr. ISAAC LEA, who is ninety-three years old, and a past President of the Association. He regretted that physical infirmities made it impossible for him to attend the meeting, but earnestly invited all the members to a reception at his summer residence at Long Branch on Saturday next. The invitation was accepted.

A cordial invitation was extended to the public to be present at all the meetings of the Association.

The PERMANENT SECRETARY then read the following letter from Mrs. ELIZABETH THOMPSON:

STAMFORD, CONN., JULY 21, 1884.

To F. W. PUTNAM,

*Permanent Secretary A. A. A. S.*

DEAR SIR:

In furtherance of my desire to do something to encourage pure science, about which we have conferred, I herewith enclose my check for one thousand dollars, payable to you as Permanent Secretary of the American Association for the Advancement of Science, to be expended by the Association, under the direction of its Standing Committee, for making experimental research upon light and heat; the results of these experimental researches to be reported to the Standing Committee of the Association.

MRS. ELIZABETH THOMPSON.

The PERMANENT SECRETARY stated that this was the second time Mrs. Thompson had advanced the objects of the Association by her liberality.

On the recommendation of the STANDING COMMITTEE a vote of thanks was given to Mrs. Thompson for her liberal gift.

The GENERAL SECRETARY then read a list of 314 persons recommended for membership in the Association and they were duly elected.

The PERMANENT SECRETARY read the financial report of the Association. This is printed in full on another page.

The PERMANENT SECRETARY also read the following list of members, notices of whose death had been received during the past year.

L. N. DIMMICK, Santa Barbara, Cal. Joined at the 29th meeting. Died May 31, 1884.

MRS. KATE N. DOGGETT, Chicago, Ill. Joined at the 17th meeting. Died March 12, 1884.

ALFRED L. ELWYN, Philadelphia, Pa. Joined at the 1st meeting. Died March 15, 1884.

DR. GEORGE ENGLEMANN, St. Louis, Mo. Joined at the 1st meeting. Born Feb. 2, 1809. Died Feb. 4, 1884.

PROF. ARNOLD GUYOT, Princeton, N. J. Joined at the 1st meeting. Born Sept. 5, 1809. Died Feb. 8, 1884.

GEORGE E. HAYES, Buffalo, N. Y. Joined at the 15th meeting.

WALTER N. HILL, Chester, Pa. Joined at the 29th meeting. Born April 15, 1846. Died March 29, 1884.

WILLIAM S. JOHNSON, Washington, D. C. Joined at the 31st meeting. Born Sept. 20, 1859. Died Oct 6, 1883.

HENRY A. JONES, Portland, Me. Joined at the 29th meeting. Died Sept. 3, 1883.

THOMAS KITE, Cincinnati, Ohio. Joined at the 5th meeting. Died Feb. 6, 1884.

DR. JOHN L. LECONTE, Philadelphia, Pa. Joined at the 1st meeting. Died Nov. 15, 1883.

REV. B. N. MARTIN, New York, N. Y. Joined at the 23rd meeting. Died Dec. 26, 1883.

THOMAS MCFADDEN, Westerville, Ohio. Joined at the 30th meeting. Born Nov. 9, 1825. Died Nov. 9, 1883.

HARRY E. PACKER, Mauch Chunk, Pa. Joined at the 30th meeting. Died Feb. 1, 1884.

B. O. PEIRCE, Beverly, Mass. Joined at the 18th meeting. Died Nov. 12, 1883. Aged 71 years.

MRS. ALMIRA HART LINCOLN PHELPS, Baltimore, Md. Joined at the 13th meeting. Died July 15, 1884, in her 91st year.

STEPHEN H. POTTER, Hamilton, Ohio. Joined at the 30th meeting. Born Nov. 10, 1812. Died Dec. 9, 1883.

SIDNEY PULSIFER, Philadelphia, Pa. Joined at the 21st meeting. Died March 24, 1884.

BENJAMIN D. SANDERS, Wellsburg, W. Va. Joined at the 19th meeting.

EZRA C. SEAMAN. Joined at the 20th meeting.

DR. J. LAWRENCE SMITH, Louisville, Ky. Joined at the 1st meeting. Born Dec. 16, 1818. Died Oct. 12, 1883.

JOSIAH A. STEARNS, Boston, Mass. Joined at the 29th meeting.

ARTHUR F. TAYLOR, Cleveland, Ohio. Joined at the 29th meeting. Died July 3, 1883.

This list contains the names of four original members of the Association, two of whom were past presidents, also the name of a former treasurer.

After formal announcements by the PERMANENT SECRETARY and Officers of the LOCAL COMMITTEE the GENERAL SESSION adjourned.

On the adjournment of the General Session the SECTIONS met in their respective section rooms to complete their organizations with the following results.

## SECTION A. MATHEMATICS AND ASTRONOMY.

*Vice President:* H. T. EDDY.

*Secretary:* G. W. HOUGH.

*Member of Standing Committee:* WILLIAM HARKNESS.

*Sectional Committee:* ORMOND STONE, J. R. EASTMAN, S. J. COFFIN.

*Nominating Committee:* C. G. ROCKWOOD.
*Sub-committee on Nomination:* W. A. ROGERS, LEWIS SWIFT, H. M. PAUL.

## SECTION B. PHYSICS.

*Vice President:* JOHN TROWBRIDGE.
*Secretary:* N. D. C. HODGES.
*Member of Standing Committee:* T. C. MENDENHALL.
*Sectional Committee:* H. S. CARHART, A. A. MICHELSON, E. H. HALL.
*Nominating Committee:* C. S. HASTINGS.
*Sub-committee on Nomination:* T. F. JEWELL, C. K. WEAD, C. THOMAS.

## SECTION C. CHEMISTRY.

*Vice President:* JOHN W. LANGLEY.
*Secretary:* HENRY CARMICHAEL.
*Member of Standing Committee:* W. R. NICHOLS.
*Sectional Committee:* W. O. ATWATER, GEO. C. CALDWELL, F. W. CLARKE.
*Nominating Committee:* S. A. LATTIMORE.
*Sub-committee on Nomination:* E. W. MORLEY, W. MCMURTRIE, C. LEO MEES.

## SECTION D. MECHANICAL SCIENCE.

*Vice President:* R. H. THURSTON.
*Secretary:* J. BURKITT WEBB.
*Standing Committee:* DEVOLSON WOOD.
*Sectional Committee:* G. LANZA, W. A. ROGERS, M. B. SNYDER.
*Nominating Committee:* C. J. H. WOODBURY.
*Sub-committee on Nomination:* J. C. HOADLEY, W. P. TROWBRIDGE, T. R. PICKERING.

## SECTION E. GEOLOGY AND GEOGRAPHY.

*Vice President:* N. H. WINCHELL.
*Secretary:* EUGENE A. SMITH.
*Member of Standing Committee:* GEO. H. COOK.
*Sectional Committee:* EDWARD ORTON, E. T. COX, E. T. NELSON.
*Nominating Committee:* H. S. WILLIAMS.
*Sub-committee on Nomination:* D. S. MARTIN, A. H. WORTHEN, J. C. SMOCK.

## SECTION F. BIOLOGY.

*Vice President:* E. D. COPE.
*Secretary:* C. E. BESSEY.
*Member of Standing Committee:* GEORGE MACLOSKIE.
*Sectional Committee:* HENRY F. OSBORNE, J. W. CHICKERING, BURT G. WILDER.
*Nominating Committee:* J. G. MORRIS.
*Sub-committee on Nomination:* WM. SAUNDERS, B. SHARP, HERBERT OSBORN.

## SECTION G. HISTOLOGY AND MICROSCOPY.

*Vice President:* T. G. WORMLEY.
*Secretary:* ROMYN HITCHCOCK.
*Member of Standing Committee:* W. H. WALMSLEY.
*Sectional Committee:* A. H. HERVEY, R. H. WARD, W. H. WALMSLEY.
*Nominating Committee:* WM. LIBBEY, JR.
*Sub-committee on Nomination:* A. P. BROWN, J. D. HYATT, C. S. SHULTZ.

## SECTION H. ANTHROPOLOGY.

*Vice President:* E. S. MORSE.
*Secretary:* G. H. PERKINS.
*Member of Standing Committee:* P. R. HOY.
*Sectional Committee:* T. F. MOSES, W. H. DALL, S. D. PEET.
*Nominating Committee:* W. H. DALL.
*Sub-committee on Nomination:* MRS. E. A. SMITH, JOHN CONE KIMBALL, J. W. POWELL.

## SECTION I. ECONOMIC SCIENCE AND STATISTICS.

*Vice President:* JOHN EATON.
*Secretary:* C. W. SMILEY.
*Member of Standing Committee:* E. B. ELLIOTT.
*Sectional Committee:* EDWARD ATKINSON, FRANKLIN B. HOUGH, E. B. ELLIOTT.
*Nominating Committee:* J. W. CHICKERING, JR.
*Sub-committee on Nomination:* P. H. DUDLEY, JOHN S. HICKS, THOMAS HAMPSON.

### THURSDAY AFTERNOON.

Addresses of the Vice Presidents were given as follows:—

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Vice | President | EDDY | before | Section | A | at | 2.30 | P. | M. |
| " | " | LANGLEY | " | " | C | " | 2.30 | " | " |
| " | " | WINCHELL | " | " | E | " | 2.30 | " | " |
| " | " | WORMLEY | " | " | G | " | 2.30 | " | " |
| " | " | MORSE | " | " | H | " | 2 30 | " | " |
| " | " | TROWBRIDGE | " | " | B | " | 4 | " | " |
| " | " | THURSTON | " | " | D | " | 4 | " | " |
| " | " | COPE | " | " | F | " | 4 | " | " |
| " | " | EATON | " | " | I | " | 4 | " | " |

### THURSDAY EVENING.

A lecture by Professor J. S. NEWBERRY, of New York, was given at the Academy of Music, at 8 o'clock. The subject was, The Geological Evolution of the North American Continent, which was illustrated by lantern pictures.

### FRIDAY, SEPTEMBER 5.

The Association met in GENERAL SESSION at 10.30 A. M., PRESIDENT LESLEY in the chair.

The following notices by the LOCAL COMMITTEE were read:— Members of the Association and representatives of foreign societies are requested to register their names at the office of the Permanent and Local Secretaries, on the first floor of Horticultural Hall, on Broad Street above Spruce, adjoining the Academy of Music, as soon as possible. Registry blanks are provided for this purpose. Members will register each member of their family (under the new rule) on separate blanks. A badge will be furnished each person so registered, upon which will be stamped the number attached to the name in the daily printed lists of arrivals. These badges are to be worn during the meeting, in order to facilitate the arrangements of the Local Committee. Each person provided with a badge will be furnished with a guide book, a map, and such circulars, notices and cards as provided for.

The members of the British Association and the representatives of other foreign societies will be designated by a supplementary purple ribbon.

Members of the Local Committee will be in attendance, and will be designated by a white ribbon on the Association badge. Members of the Sub-committees on Receptions and Invitations, Hotels, Luncheon and Lodings, and Transportation, will give such information on the subjects of which they have charge as may be desired.

The representatives of the press will be provided with a yellow badge.

In order to secure accuracy authors are requested to furnish reporters with abstracts of their papers.

Through the liberality of the Western Union Telegraph Company, social telegrams for members of the American and British Associations will be sent during the meeting from Philadelphia to all parts of the United States and Canada free of charge; and by an arrangement among the Atlantic cable companies, social messages will be transmitted to Europe for the members of the British Association without charge, on presentation of certificate.

The ladies of the Century Club, No. 1112 Girard Street, have offered the use of their house for the accommodation of ladies attending the meetings. It will be found a desirable place for rest for those who are fatigued during the day and who desire intellectual companionship.

The University Club has extended a formal invitation by card, to each member of the American and British Associations for the Advancement of Science, the Royal Society of Canada, and the Delegates of Scientific Societies duly accredited to this meeting.

The Union League have also offered the privileges of the club house to the gentlemen above mentioned.

The Philadelphia Library, Northwest corner of Locust and Juniper streets, together with the Ridgway branch of the same, a superb building occupying the square between Broad, Thirteenth, Carpenter and Christian streets, has been kindly placed at the disposal of members and visitors during the session.

A Committee of ladies will be in attendance at the Academy of Natural

Sciences, N. W. cor. 19th and Race Sts., Friday afternoon from 3 to 6 P. M., for the reception of ladies who desire to inspect the museum and library. As the collections in some departments are unrivalled in point of completeness, the opportunity should be taken to visit the institution at this time. The museum and library, however, will be open to all attending the meeting, every day from 9 A. M. to 5 P. M. during the session.

The Woman's Medical College, Twenty-first street and North College avenue, tenders to the American and British associations and representatives of foreign societies, with their families, a reception on the afternoon of Monday, September 8th, from 4 to 7 o'clock.

The Directors of the Zoological Garden will furnish, to all provided with the Association badge, cards of free admission to the grounds in Fairmount Park, which can be used at any time during the session. A special invitation is extended to visit the Garden on the afternoon of Monday, September 8th, from four to six o'clock, when Mr. Eadward Muybridge will demonstrate his method of taking instantaneous photographs of animals while in motion.

All botanists, members of the Association, are requested to call and register at the Academy of Natural Sciences, Nineteenth and Race streets, as soon as practicable. This will constitute them members of the Botanical Club of the Association (instituted at the Minneapolis meeting), and entitle them to the privileges of the same. They will find a Reception Committee in attendance at the Academy of Natural Sciences, on Thursday and Friday, September 4th and 5th, to promote acquaintance and to furnish information upon botanical matters. The Botanical Section of the Academy will meet at their hall on Monday evening, September 8.

Those who have not been furnished with tickets for the International Electrical Exhibition will be supplied upon application at the Local Secretaries' desk.

An invitation is extended to visit the rooms of the Women's Silk Cultural Association, No 1328 Chestnut St.

Dr. Isaac Lea, Past President of the Association, invites biologists interested in conchology to visit his collection at 1622 Locust street.

On Saturday, September 6th, excursions will be offered to members of the Associations and foreign delegates, their families, and invited guests, to the anthracite regions and to the seaside. The Committee on Transportation and Excursions has furnished the following details:—

BY THE PENNSYLVANIA RAILROAD COMPANY.

Three seashore excursions will be given, as follows:—

TO LONG BRANCH.

Leaving Broad Street Station at 8 A. M., arriving at Long Branch at 10.50 A. M.

Reception by Past President, ISAAC LEA, LL.D., from 3 to 5 o'clock.

Returning, leave Long Branch at 5.10 P. M., and arriving at Broad Street Station at 8.10 P. M.

Dinner furnished by the Philadelphia Local Committee at West End Hotel.

TO ATLANTIC CITY.

Leaving Vine Street Wharf at 9 A. M., arriving at Altantic City at 10.30 A. M.

Returning, leave Atlantic City at 5.40 P. M., arriving at Vine Street wharf at 7.20 P. M.

Dinner furnished by the Philadelphia Local Committee at a hotel to be announced.

FOR CAPE MAY.

Leaving Market Street wharf at 9 A. M., arriving at Cape May at 11.25 A M.

Returning, leave Cape May at 4.40 P. M., arriving at Market Street wharf at 7.20 P. M.

Dinner furnished by the Philadelphia Local Committee at Congress Hall.

Each of the three seashore excursions of the Pennsylvania Railroad Company will be in charge of members of the Local Committee, assisted by an excursion agent of the company.

BY THE PHILADELPHIA & READING RAILROAD COMPANY.

TO THE ANTHRACITE COAL REGIONS (in conjunction with an excursion to the American Institute of Mining Engineers); leaving Broad and Callowhill streets at 8 o'clock, A. M., and returning the same day.

This excursion will be directed by Mr. Charles A. Ashburner, who is in charge of the Pennsylvania Geological Survey of the anthracite coal fields.

A lunch will be furnished by citizens of the coal regions, and supper on the return, by the Philadelphia Local Committee.

Tickets for this trip will be good on any regular train for a continuous passage over the Philadelphia & Reading Railroad or the Lehigh Valley Railroad, on Sunday, September 7th and on Monday, September 8th, to Philadelphia, thus enabling members to pass Sunday at Mauch Chunk or Wilkesbarre, if they so desire.

A BOTANICAL EXCURSION will be made to the pine barrens of New Jersey, where will be found a flora peculiar and full of interest. The point selected is Egg Harbor Station, on the Camden and Atlantic Railroad. Boats for the train leave Vine Street Ferry (Delaware River) at 9 A. M. A lunch will be served by the Philadelphia Local Committee on a car switched off for the purpose. Those who participate will have the option of proceeding in the afternoon to the seashore at Atlantic City, or of returning on a regular train leaving Egg Harbor at 4.34 P. M., and arriving in Philadelphia at 6.20. Those desirous of joining in this excursion will register their names with the Railroad agent at Horticultural Hall on or before Friday noon, September 5th.

A GEOLOGICAL EXCURSION to points of interest in the vicinity of the city, will be taken by the geological section on an afternoon yet to be announced.

On Monday evening, September 8, there will be a joint meeting and social reunion of the Botanical Club of the Association and the Botanical

Section of Philadelphia Academy of Natural Sciences, at the hall of the Academy, corner of Race and Nineteenth streets. All members of the American Association and representatives of foreign societies with their families are cordially invited to be present. Invitations have been extended to the Torrey Botanical Club, of New York, to the Ladies' Botanical Club, of Germantown, and to all neighboring botanists. Those who will attend will confer a favor by registering their names at the Local Committee Room.

Reception by the Local Committee, Provost, Trustees and Faculties of the University of Pennsylvania in the College Hall, Thirty-fourth and Spruce streets.

Invitations have been issued by the Woman's Medical College for a reception, from 4 to 7 P. M., and the experiments of Mr. Eadward Muybridge, on the Instantaneous Photographing of Animals in Motion, will take place at the Zoological Gardens, from 4 to 6 o'clock, P. M.

On Tuesday afternoon, September 9, the botanists of the Association are invited to join the members of the Botanical Section of the Academy of Natural Sciences in a pilgrimage to the old Bartram House and Botanical Garden at Kingsessing, four miles from Philadelphia. Cars will leave Broad Street Station of the Pennsylvania Railroad, at 4.25 P. M., stopping at Fifty-eighth Street Station, leaving latter point for return at 6.17 P. M. Those desirous of joining in this excursion will please register their names at the Local Committee Room, before Monday noon, eighth inst.

In the evening a reception and exhibition of microscopes and microscopical objects will be given by the Biological and Microscopical Section of the Academy of Natural Sciences, in the hall of the Academy, southwest corner of Nineteenth and Race streets. During the microscopical reception at the Academy of Natural Sciences, the museum will be open for inspection and the members of the Association are cordially invited to be present.

On the same evening a lecture will be delivered in the Academy of Music by Prof. ROBERT S. BALL, Astronomer Royal of Ireland. Subject: "The Distances of the Stars;" after which a reception will be given by the Local Committee in the Pennsylvania Academy of Fine Arts, at the corner of Broad and Cherry streets, to the members, with their families, of the two Associations, of the Royal Society of Canada, and of other foreign scientific societies.

On Wednesday afternoon, September 10, the members of the American and British Associations for the Advancement of Science, and of other scientific bodies, with their families, are invited by the Ladies' Reception Committee to a lawn party at Haverford College, distant nine miles from the city on the line of the Pennsylvania Railway. Special trains will leave Penn. R. R. Station, Broad street, at 4.45 and 5.45 P. M., returning 7.50 and 9.30 P. M. Tickets can be procured at an especial entrance gate at the station on the members showing their badges.

An invitation is also extended by the managers of the International

Electrical Exhibition to inspect the exhibits. Special facilities will be offered by the managers of the exhibition on this day, and it is recommended to persons having professional or technical interest in this exposition to visit it by daylight as well as in the evening.

The GENERAL SECRETARY submitted a list of eighty-four names of persons who had been nominated for membership, and they were elected.

Dr. C. S. MINOT then said: I have the honor, ladies and gentlemen, to present for your respectful consideration, a subject which has been deemed a most important one by many members of the Association. I allude to the proposed organization of an international scientific congress. The movement has taken shape in the drafting of a petition, signed by the names of many eminent men, for presentation to both the British and American Associations. The petition is as follows: "The undersigned respectfully request the British Association for the Advancement of Science and the American Association for the Advancement of Science to consider the advisability of forming an international scientific congress, to meet at intervals in the different countries, and, if it should be found desirable, to take measures to initiate the undertaking." This is an entirely spontaneous movement, and has, in view, in the fullest sense, the advancement of the cause which is of mutual interest to every one of us. The British Association, at its recent session in Montreal, received this petition most cordially and courteously, and appointed as the Committee to consider the proposition, three of its most eminent members: Sir William Thomson, Sir Lyon Playfair, and Mr. Vernon Harcourt. They will consult with the Committee of this Association appointed yesterday, namely: Professors S. Newcomb, T. Sterry Hunt, G. F. Barker, E. C. Pickering, J. W. Powell, Ira Remsen and C. S. Minot. It is with great pleasure that I bring this matter before you today. I feel, however, that this is not the occasion for any further comment upon the matter, and we must await the deliberations of those to whom the subject has been referred.

The GENERAL SESSION then adjourned.

## FRIDAY EVENING.

RECEPTION AT THE ACADEMY OF MUSIC, at 8 o'clock. President LESLEY introduced the Hon. JOHN WELSH, Chairman of the Local Committee, who, in a short speech on behalf of the citizens of Philadelphia, welcomed the visiting scientists to the city. He said:

The large number of scientists who are gathered to-night in the Academy indicate the extent and numerousness of the devotees at the shrine of Science, who are seeking to learn of the mysteries and manifold powers of Nature, of her ways known and unknown. Her wonderful daily unfoldings are apparently inscrutable. In searching out the methods of divinity in the administration of the universe the noblest faculties of man are called into action. Science moves slowly from point to point, each advance forming a stepping stone to farther progress. The aim of science is the amelioration of the condition of mankind, to lighten human burdens and help on human industries.

We tender you, then, as missionaries in this great march of intellectual progress, a cordial welcome to Philadelphia, and may your stay in our midst be productive of lasting and pleasant recollections of us. Again, I say, thrice welcome.

Dr. WILLIAM PEPPER, Chairman of the Committee of Invitations and Reception, after a few introductory remarks, spoke as follows:—

The importance of this meeting is to be readily recognized, not only by the large numbers in attendance, but far more by the character of the audience I have the honor of addressing. Although no banners float in the breeze, and though no rival bands fill the air with confused and hideous noises, the thoughtful mind will recognize in this meeting a convention of vastly more importance to the future interests of our nation and our race than are those noisy assemblages where personal preëminence, not permanent principles, is the subject of contention.

Only thirty-six years have passed since the initial meeting of the American Association for the Advancement of Science (the outgrowth of the Association of American Geologists and Naturalists) was convened in this city, and its organization was effected in close conformity with that of the British Association for the Advancement of Science.

The number in attendance was small, and the proceedings attracted little or no attention outside of scientific circles; in succeeding years the larger meetings and the well-known names which appeared among the contributors, drew from the press brief notices, often of quizzical tone; but later still it began to be recognized that these annual gatherings of scientists were significant events, and that, instead of barren discussion of abstract matters absorbing their time, very many observations and inventions of the greatest practical importance yearly appeared in their transactions, and thus finally it has come about that any such international scientific meeting as the present is regarded with intelligent interest by the entire community, who appreciate that our scientific labors are closely connected with the progress of civilization, and with the advancement of human welfare. It is to this demonstration that modern science does deal directly with the chief human interests that its marvellously rapid advance in the estimation of the public is due. And when it is fully realized that this modern science not only aims to secure, in the language of Emerson, 'the extension of man on all sides into nature till his hands shall touch the stars, his eyes see through the earth, his ears understand the language of beast and bird, and the sense of the wind, and through his sympathy heaven and earth shall talk with him,' but further that, through its marvellous interpretation and adaptation of the forces and laws of nature, man now for the first time is being slowly brought into closer harmony with his environment, and thus fitted for fuller evolution in accordance with the cosmical changes ceaselessly progressing around him, then it will be willingly conceded that the work in which this association is so successfully engaged, is the most important and beneficent which has ever engaged the activities of our race.

It is becoming possible to form dim conceptions of the past history of

man and of the successive stages by which he has emerged from the period of the river drift and of the cave dwellers; and science is teaching us how, through ignorance and inability to cope with the adverse forces of nature, successive races of man have been displaced, dispersed or destroyed, and through what painful struggles for subsistence has the race gained its present development; but who will dare foretell the possibilities of human progress or of the elevation of a race inheriting an ever-increasing wealth of moral, mental and physical attainments; or assert that with such advancing intimacy with nature's laws, we shall not yet conquer in the Titanic struggles which may await us in the distant future? Of such laws, and of no human legislation, was it sublimely said: 'Her seat is the bosom of God, her voice is the harmony of the world.' Nor does it need any word at this day to defend the researches of science, the interpreter of nature, whether into the past or the future, as the noblest and most attractive and fruitful topic which can engage the mind of man.

It is true that with each year there is increasing public appreciation of the work and claims of scientists. We have but recently seen the gates of England's great Abbey open to receive among her famous dead not only the immortal Darwin, but another whose claim to entrance there was that he had been the chosen and fitting representative of England's scientists. But in this country there is needed more practical and immediate expression of this rising appreciation. Science itself is ultimately practical and profitable; but with no such motive as that of profit or immediate utility must the true scientist pursue his researches. Nor can we afford to delay the formation of such ample endowments as will enable the gifted and disinterested men whom we expect to advance our national scientific fame to prosecute their labors; and which will render our great universities true centres of fruitful scientific work, extending their influence throughout the world.

The importance of this endowment of scientific research is, to my mind, one of the greatest lessons of this interesting occasion; and I have gladly availed myself of the opportunity of alluding to it while discharging the grateful duty of extending to you, as I now do, a most cordial welcome on behalf of the scientific workers of Philadelphia, of whom, whether of the past or of the present, I am proud to be able to say that they include many whose name and fame the world will not willingly let pass away.

The retiring President C. A. YOUNG then gave his address, which is printed in full in the present volume.

Dr. BALL, the Astronomer Royal of Ireland, was called for amid cheers, and, in behalf of the British Association and the foreign delegates, spoke as follows:

I am sorry that some one else was not chosen to respond to this overwhelming testimony of cordiality and kindly feeling of the citizens of Philadelphia. I was picked out, however, I suppose, because I have been in this country longer than the rest of my associates. These have been here only twelve hours, while I have been here fifteen hours. A big difference you see.

I feel sure that I am expressing the sentiments of those for whom I speak, when I thank you warmly and heartily for your very kind greeting that you have extended to us. I wish to thank you also, for your cordial hospitality, which makes us feel that we shall have an enjoyable and profitable visit to this great and beautiful city.

I want to say a word with regard to Professor Young's theory about sun spots. If any one on our side of the Atlantic should have the courage to advance the belief that there are no sun spots he would have many scientists down upon him. However, I have not yet heard whether the sun spots give us good or bad weather.

There is danger of astronomers falling into the fool's paradise, by relying too implicitly upon the mathematical formulas and theories already laid down for their guidance. They are not always accurate or to be depended upon implicitly. One object of science is to clear up these mistakes and discrepancies.

Dr. BALL'S remarks brought the formal exercises to a close, and the rest of the evening was given up to an informal promenade and a general reception of the delegates, characterized by much hand-shaking, and terminating with a bountiful collation.

SATURDAY, SEPT. 6.

No meetings of the Association were held. The day was devoted to excursions to Cape May, Atlantic City, Long Branch, the Coal regions, and other places. The members of the Association were handsomely entertained at all these places, and to the Local Committee was given great praise for the admirable manner in which the programme was carried out. The Long Branch party was entertained by Dr. Isaac Lea, Ex President Grant, Dr. Da Costa, and Mr. Anthony Drexel.

The trip to the Coal Regions was a complimentary one, tendered by the Philadelphia and Reading Railroad, and was made chiefly successful by the efforts of Mr. Chas. A. Ashburner, chairman of the joint excursion committee S. B. Whiting, of the Reading, and Joseph S. Harris of the Lehigh Valley Railroad.

MONDAY, SEPT. 8, 1884.

The Association met in GENERAL SESSION at 10 A. M. Owing to the illness of President LESLEY, Prof. E. D. COPE, the senior Vice President, occupied the chair.

The GENERAL SECRETARY read the names of forty-nine persons who had been nominated for membership, and they were elected.

The PRESIDENT announced that the reports of Special Committees were now in order.

The "Permanent Committee on Weights, Measures and Coinage" reported progress and was continued.

The "Committee on Membership" was continued.

The "Committee on the best methods of Science-teaching in the Public Schools" was reorganized with power to add to its number.

The "Committee on the Registration of Deaths, Births and Marriages" reported and was continued.

The "Committee on Stellar Magnitudes" made a report, which will be found on page 29, and was continued.

The "Committee to confer with Committees of Foreign Associations for the Advancement of Science with reference to an International Convention of Scientific Associations" was reorganized, and reported as follows:

1. That this committee be empowered to act.

2. That, after being officially advised of the willingness of a sufficient number of foreign societies to coöperate, it unites with such bodies to form a corporation under a suitable name, in order to hold property legally, and receive the gift of Mrs. Elizabeth Thompson.

3. That the British Association be invited to appoint a representative Committee to further coöperate with this Committee.

The "Committee on Indexing the Literature of the Chemical Elements" sent a report which will be found on page 31 and was continued.

The "Committee on International Congress of Geologists" reported and was continued.

The "Committee to Confer with the United States Geologist in regard to coöperation between the Government and State Geological Surveys" reported and was continued.

The following resolutions offered by Prof. W. P. TROWBRIDGE, of Columbia College were adopted.

*Resolved*, That in view of the rapid increase and extension in this country, of the interests which depend on accurate surveys and maps, especially in connection with the engineering, mining, geological and agricultural professions and industries, it is the sense of this Association that Congress should provide at once for the extension for geodetic and topographic surveys over the whole country without regard to state boundaries.

*Resolved*, That the President of this Association be requested to transmit copies of this resolution to the Speaker of the U. S. House of Representatives and to the President of the Senate.

On presenting these resolutions, Prof. TROWBRIDGE said:—

MR. PRESIDENT: It is hardly necessary to enter into any discussion before this Association concerning the necessity and the importance of accurate maps of a country like ours, where all the industries, sciences and enterprises which depend on such maps are daily and rapidly increasing in importance.

Nor is it necessary to refer to the existing maps known as state, county and town maps, except to reiterate what has been so often brought before the public concerning their glaring defects and often gross inaccuracies.

Based, as these maps usually are, upon crude surveys made with the magnetic compass and rough chaining, it is impossible that they should possess any elements of accuracy; while some of the most important features of all good maps, such as contour lines showing elevations, etc., are in these maps, entirely wanting, and all details are often mere fancy work.

Brief reference only need be made to some of the objects for which the best topographical maps are now in pressing demand.

Among these, the most important are Geological Surveys, which, beside their general scientific bearings, have immediate practical applications to the developments of the mineral wealth of the country; engineering enterprises, notably the sanitary drainage of malarious districts, the supply of water to towns, the reclamation of low and moist lands, and the irrigation of arid tracts of which there are such large areas in our Western states and territories.

Much might be said in regard to benefits to agriculture and the improvements of lines of communication, affecting state and interstate commerce, which must immediately follow the execution of accurate maps.

It may be taken for granted that there will be found little difference of opinion among our scientific men on all these questions.

But the resolution which I hope to see passed looks to an important modification of the policy pursued by the governments up to the present time; a policy which has been accepted by the public for no other reason, it seems to me, than the simple fact that this policy has never been the subject of serious discussion by men of science in this country.

It has been taken for granted that as far as our sea coasts and the shores of the great lakes are concerned, the interests of commerce, which are plainly common to all, point to the execution of surveys by the general government; while it has at the same time tacitly admitted that although preliminary reconnaissance, and explorations of our territories should also be made by the government yet so soon as a state is organized, all surveys, including those which alone deserve the title of accurate geodetic and topographic surveys, must be executed by the states themselves, at their own will and pleasure, and according to their own methods.

It is not difficult to see that under this public policy there can never be a thorough survey of this country as a whole, nor of any considerable part of it.

It is next to impossible for several states to unite on one system, and to conduct surveys which shall be properly united along their borders. We have all seen how difficult it has often been for two states to decide through commissioners appointed by their legislatures, upon the exact boundary between them; and those who have endeavored to secure the favorable action, of a single state legislature, on the subject of a geodetic and topographic survey of a state, and who have been discouraged by the apathy of state legislatures will appreciate the hopelessness of the task of obtaining united and concurrent legislation in several states.

Without such concurrent action on the part of many states, in which questions of control, division of labor and costs, the execution of the field and office work, and the construction of maps, must all enter into the discussion, it must be seen that the execution of general geodetic and topographic surveys of the country by the states themselves is impracticable.

State boundaries should not be allowed thus, without any sufficient reason to become insurmountable barriers to the execution of a public work

of such importance as the accurate survey of a country like ours, where the interests involved are general as well as local. In all countries where such surveys have been made, — and the list of these would be a mere enumeration of the states of Europe, — the government has not only controlled the surveys but supplied the means for their execution.

It must, I think be recognized here, as it has been everywhere else, that the subordinate political divisions of a country ought not to control and execute the separate parts of a public work which from its very nature cannot be properly thus subdivided, and finally it may be urged that a national survey of the character contemplated in this resolution is one of the most important of all the sources of increased national wealth and prosperity.

"The Committee in relation to Duties on Scientific Books" reported that relief may be expected on books for those engaged in scientific research, and the committee was continued.

Prof. C. A. YOUNG, of Princeton, Chairman of "the Committee on Interchange of Courtesies between the American and British Associations for the Advancement of Science" said that the gentlemen composing the Committee had no written report. They preferred that what they had to say should come warm from the heart. The presence here of so many English friends shows with what success the efforts of the committee have been attended. The cordiality between the two associations is manifest enough. I therefore ask that we be discharged.

At this moment half-a-dozen British members jumped up and requested that a vote of thanks to the Committee be unanimously agreed upon. This suggestion was favorably received, and was on the point of being put, when Prof. CARVILL LEWIS, one of the Local Secretaries, rose and said: Before the Committee is discharged and its members are once more distributed, I would like to know if it is not possible through something they may do to secure a continuance and permanency of the very pleasant relations which to-day exist between our foreign friends and ourselves. [Applause] I should like to feel that there was an arrangement by which in the future the bond of union between the two great countries may become stronger and stronger. It would be a good thing to secure to the English scientist when he visits this country in after years a membership for the time being in our American Association. It would also be satisfactory to know that when an American visits Great Britain he will feel the warm brotherly friendship that comes of a mutuality of interest. Our constant interchange of courtesies may, too, have another reason for existing in an organized manner. By their continuance it will be possible to obtain from the steamship companies such a reduction of rates as will allow members of the Association on one side of the water to frequently attend the sessions of the Association on the other side. I therefore suggest, if the Chair be willing, that the Committee continue, in the hope that they may keep on solidifying the friendly feeling between the countries.

Professor YOUNG said that the Committee would be pleased to continue on such pleasant work.

Prof. TRELAWNEY SAUNDERS said: I would like to say a few words on behalf of my countrymen who have been so liberally treated at your hands. I am not speaking at their suggestion, but I know that I can take upon myself to say for them that they are highly delighted at your hospitality. Not only are they grateful for what has been done for them personally, but they are pleased to meet with so much kindly feeling towards their country in general. You are brothers truly, and never before did we realize it so forcibly. What you have done and what you have said will do something to increase the affection with which the people of both countries naturally regard each other. You came from us; you are our flesh and blood and you are Englishmen. Time has effaced a few trifling characteristics which formerly were common to both; but Englishmen are getting Americanized, and Americans are getting Anglicized. Differences are disappearing. A few years hence we shall be as one nation, each country having acquired the virtues and good qualities of the other and both being benefited. Anything like an international science congress will be well received by your brothers over the water.

A vote of thanks was given the Committee and it was also voted that it be continued.

The GENERAL SESSION then adjourned.

In the evening there was a reception at College Hall, tendered by the Local Committee, Provost, Trustees and Faculty of the University of Pennsylvania.

TUESDAY, SEPT. 9.

The Association met at 10.30 A. M. in GENERAL SESSION. President LESLEY was still unable to preside and Vice President E. D. COPE took the chair.

The GENERAL SECRETARY read a list of twenty-eight persons recommended for membership in the Association, and they were duly elected.

Invitations to visit the Wagner Free Institute of Science, and the Girard College were received and accepted, and Tuesday afternoon agreed upon for a visit to them.

The GENERAL SECRETARY read the names of Fellows, recommended by the Nominating Committee for officers for the meeting to be held in 1885, and they were elected by the Association and are as follows:—

*President:* H. A. NEWTON, of New Haven, Ct.

*Vice Presidents:* **A.** *Mathematics and Astronomy*—J. M. VAN VLECK, of Middletown, Ct.; **B.** *Physics*—C. F. BRACKETT, of Princeton, N. J.; **C.** *Chemistry*—W. R. NICHOLS, of Boston, Mass.; **D.** *Mechanical Science*—J. BURKITT WEBB, of Ithaca, N. Y.; **E.** *Geology and Geography*—EDWARD ORTON, of Columbus, O.; **F.** *Biology*—BURT G. WILDER, of Ithaca, N. Y.; **G.** *Histology and Microscopy*—S. H. GAGE, of Ithaca, N. Y.; **H.** *Anthropology*—W. H. DALL, of Washington, D. C.; **I.** *Economic Science and Statistics*—EDWARD ATKINSON, of Boston, Mass.

*Permanent Secretary:* F. W. PUTNAM, of Cambridge (office, Salem, Mass.).

*General Secretary:* CHARLES SEDGWICK MINOT, of Boston, Mass.

*Assistant General Secretary:* CHARLES C. ABBOTT, of Trenton, N. J.

*Secretaries of the Sections:* **A.** *Mathematics and Astronomy*—E. W. HYDE, of Cincinnati, O.; **B.** *Physics*—A. A. MICHELSON, of Cleveland, O.; [since resigned]; **C.** *Chemistry*—F. P. DUNNINGTON, University of Virginia, Va.; **D.** *Mechanical Science*—C. J. H. WOODBURY, of Boston, Mass.; **E.** *Geology and Geography*—H. CARVILL LEWIS, of Germantown, Pa.; **F.** *Biology*—C. H. FERNALD, of Orono, Me.; **G.** *Histology and Microscopy*—W. H. WALMSLEY, of Philadelphia, Pa.; **H.** *Anthropology*—ERMINNIE A. SMITH, of Jersey City, N. J.; **I.** *Economic Science and Statistics*—J. W. CHICKERING, of Washington, D. C.

*Treasurer:* WILLIAM LILLY, of Mauch Chunk.

The NOMINATING COMMITTEE also announced that Bar Harbor, Mount Desert, Me., had been suggested as the place of meeting for the next annual session of the association. Professor COPE said that the Committee had thought that the Permanent Secretary should have a certain amount of discretion as to whether Bar Harbor should be the actual meeting-place, because it may be that, after communicating with the people of that place, he might find that sufficient accommodations could not be secured. In that event the association would have to be called elsewhere. An alternate place suggested by the committee was Ann Arbor, Mich.

A member announced his intention of offering at the next annual meeting a resolution providing that applicants for membership in the association should be disposed of by the Standing Committee, to save the time of the general session. This suggestion was heartily applauded.

Dr. MINOT then made an announcement that stirred the hearts of his hearers with enthusiasm. "Mrs. Elizabeth Thompson," he began, when he was interrupted by applause, "has notified me that she will contribute $5000 for the promotion of original scientific research, with the promise of an additional $5000 if the proposed International Congress is effected. She also expresses her readiness to contribute another $5000 next year, on condition that $10,000 is raised by other people towards promoting the same object. The committee so far has come to no definite conclusion respecting an International Congress, but this generous offer of Mrs. Thompson's has much enlarged the chances of its being brought about. But it will take money, and I appeal to you to come forward and assist us and induce your friends to contribute something in the way of substantial support. Now is the critical stage of the proposition. Unless we do something now it will have to lapse probably for several years by reason of it losing the splendid contribution which I have just announced."

A vote of thanks to Mrs. THOMPSON was carried by acclamation.

A cablegram was received from C. B. Norton, secretary of the American Exhibition which is to be held in London two years from now. It read as follows: "Hope you will arrange to meet us in London in 1886."

The PERMANENT SECRETARY announced that he had received notice that the complimentary use of the Western Union Telegraph Office in the building, which had been tendered to members of both associations by the

corporation, was in danger of being abused by the unreasonable exactions of a few members.

The GENERAL SESSION then adjourned.

WEDNESDAY, SEPT. 10.

The GENERAL SESSION took place at the Academy of Music at 10 A. M., with Vice President COPE in the chair.

The following letter was read:—

PHILADELPHIA, SEPT. 8, 1884.

PROF. F. W. PUTNAM, PERMANENT SECRETARY, A. A. A. S.

DEAR SIR:

The undersigned, residents of Toronto, Canada, beg to suggest that city as the place of meeting of the A. A. A. S. for 1886, and have every confidence in assuring the Association of a hearty reception from all classes of the community, should it be decided to meet there. In order, however, that there should be ample time given for organizing and completing the arrangements necessary to receive the Association in a becoming manner, we would request the Standing Committee now to take such steps as they can towards giving us an assurance that Toronto shall be the place of meeting. On getting such an assurance, we shall take the necessary steps towards organizing our forces there.

Please inform the Committee that this is the second invitation to Toronto, one of us [Prof. Loudon] having sent an invitation to the Cincinnati meeting, accompanied by assurances from the Ontario Government, the University of Toronto, and other institutions.

J. LOUDON.
CHARLES CARPMAEL.

The STANDING COMMITTEE announced that it was desirable that the Association meet in Toronto in 1886 or 1887.

The following resolution, approved by the STANDING COMMITTEE, was adopted:—

*Resolved*, That the following committee is hereby appointed to report at a future meeting, on the use of Graphic Illustrations in representing facts in statistics and principles of science, with the view of obtaining uniformity of rules in their construction; viz.: FRANKLIN B. HOUGH,* E. B. ELLIOTT, J. E. HILGARD, CHARLES WARREN, WILLIAM KENT.

Ten new members were elected.

The following members, recommended by the STANDING COMMITTEE, to be Fellows of the Association were then elected by ballot:

Aughey, Prof. Samuel, University of Nebraska, Lincoln, Neb. (29).
Beyer, H. G., Passed Ass't Surgeon U. S. N., care Bureau of Med. and Surg., Navy Dep't, Washington, D. C. (31).
Blake, Prof. John R., Greenwood, S. C. (29).
Brackett, Solomon H., St. Johnsbury, Vt. (29).

* Since deceased.

Brewster, William, 61 Sparks St., Cambridge, Mass. (29).
Channing, Dr. Wm. F., Providence, R. I. (29).
Chase, Prof. Pliny E., Haverford College, Haverford, Pa. (18).
Clarke, Miss Cora H., Jamaica Plains, Mass. (29).
Coulter, Prof. John M., Crawfordsville, Ind. (32).
Diller, J. Silas, U. S. Geological Survey, Washington, D. C. (29).
Dodge, J. Richards, Washington, D. C. (31).
Dodge, Prof. James A., Minneapolis, Minn. (29).
Dow, Capt. John M., 69 Seventh Ave., New York, N. Y. (31).
Dudley, P. H., 66½ Pine St., New York, N. Y. (29).
Emery, Albert H., Stamford, Conn. (29).
Foye, Prof. J. C., Lawrence University, Appleton, Wis. (29).
Gissler, Carl F., Ph. D., 63 Broadway, Brooklyn (E. D.), N. Y. (29).
Gratacap, L. P., Ph. D., M. A., American Museum Natural History, Central Park, New York, N. Y. (27).
Haliburton, R. G., Q. C., Ottawa, Can. (31).
Hall, Prof. Lyman B., Haverford, Pa. (31).
Haynes, Prof. Henry W., 239 Beacon St., Boston, Mass. (28).
Herrick, Clarence L., Granville, Ohio (31).
Hoadley, J. C., 28 State St., Room 28, Boston, Mass. (29).
Iddings, Joseph P., U. S. Geological Survey, Washington, D. C. (31).
Jayne, Horace F., 1826 Chestnut St., Philadelphia, Pa. (29).
Martin, Prof. William J., Davidson College, N. C. (31).
Minot, Francis, M. D., 65 Marlborough St., Boston, Mass. (29).
Norton, Lewis M., Ph. D., Mass. Inst. of Technology, Boston, Mass. (29).
Osborn, Herbert, Ames, Iowa (32).
Pohlman, Dr. Julius, Buffalo, N. Y. (32).
Richardson, Clifford, Dep't of Agric., Washington, D. C. (30).
Ryder, John A., Smithsonian Institution, Washington, D. C. (33).
Sharpless, Stephen P., 13 Broad St., Boston, Mass. (29).
Smith, Goldwin, The Grange, Toronto, Can. (29).
Wachsmuth, Charles, Burlington, Iowa (30).
Watson, Prof. Wm., Boston, Mass. (12).
Wood, Dr. Wm., Portland, Me. (29).
Woodbury, C. J. H., 31 Milk St., Boston, Mass. (29).
Woodward, Prof. Calvin M., St. Louis, Mo. (32).

Among the invitations read by the Secretary was one from the Ladies' Reception Committee, inviting the members and their families to a lawn party at Haverford College in the evening. An invitation was also extended by the managers of the Electrical Exhibition to inspect the exhibits. These invitations were accepted.

The GENERAL SESSION then adjourned.

THURSDAY, SEPT. 11.

The Association met in GENERAL SESSION at 10.30 A. M. Vice President COPE in the Chair. Twenty new members were elected.

A Committee was appointed to memorialize Congress or some other suitable body to supply the means for scientific investigation of Fermenta-

tion and its effects. The Committee was composed of: ALFRED SPRINGER, F. W. CLARKE, G. M. STERNBERG, H. W. WILEY and CLIFFORD RICHARDSON.

A Committee of five was appointed to consider the subject of Anatomical Nomenclature with especial reference to the Brain.

Committee: JOSEPH LEIDY, HARRISON ALLEN, H. OSBORN, T. B. STOWELL and B. G. WILDER.

A Committee was appointed on the encouragement of researches upon the Health and Disease of Plants: J. C. ARTHUR, C. E. BESSEY, T. J. BURRILL, W. G. FARLOW, J. T. ROTHOCK, C. H. PECK and W. J. BEAL.

The following committee on Physics Teaching was appointed: T. C. MENDENHALL, W. H. ANTHONY, H. S. CARHART, F. H. SMITH and JOHN TROWBRIDGE.

The following resolutions were received from SECTION F:

*Resolved*, 1. That the Biological Section of the American Association for the Advancement of Science earnestly requests the Postmaster General to recommend to Congress such changes in the existing postal laws as will permit the transmission through the mails of botanical specimens accompanied with the customary written labels, giving name, locality date of collection and collector's name, at fourth-class rates of postage.

2. That he will take such action as may be deemed best to secure similar regulations in the transmission of botanical specimens to and from Canada.

3. That he will cause the same subject to be presented before the Congress of the Universal Postal Union at its meeting in Lisbon, in October next, in order, if possible, to secure like liberality with foreign countries.

The Secretary was requested to transmit the resolutions to the Postmaster General, and the following Committee was appointed to wait upon the Postmaster General to bring the matter more fully to his attention: L. F. WARD, GEO. VASEY and J. W. CHICKERING.

The COMMITTEE to consider the advisability of designating, in the printed list of members, the various sections in which each member is principally interested, by putting the characteristic letter of those sections after his name, reported as follows:

They recommend that the Permanent Secretary shall be directed to issue a circular to every member of the Association, asking him to indicate those sections of the Association in which he is principally interested.

It was voted to distribute the Philadelphia volume of the Proceedings to the foreign delegates and the members of the British Association present at this meeting.

The GENERAL SESSION then adjourned.

### THURSDAY EVENING SESSION.

The Association held its final meeting in GENERAL SESSION at the Academy of Music. President LESLEY in the Chair. The ASSISTANT GENERAL

SECRETARY, Dr. MINOT, read a resolution which gave the thanks of the Association to His Excellency, ROBERT E. PATTISON, Governor of Pennsylvania. and to His Honor, WM. B. SMITH, Mayor of Philadelphia.

To the LOCAL COMMITTEE for the laborious and successful care in perfecting all arrangements for the meeting.

To the LADIES' RECEPTION COMMITTEE for their many and agreeable attentions.

To Gen. H. S. HUIDEKOPER for admirable arrangements of the Association Post Office and telegraph.

To the REPRESENTATIVES OF THE PRESS.

To the TELEGRAPH AND TELEPHONE COMPANIES for privileges granted.

To the PENNSYLVANIA, READING and LEHIGH RAILROADS, for privileges and hospitalities granted and the kind attentions shown during the excursions to the members.

To Prof. C. A. ASHBURNER, for attentions on the excursions to the coal fields.

To the EXPRESS COMPANIES and UNION TRANSFER COMPANY, for advantages offered and services rendered.

To the UNION LEAGUE, EPISCOPAL ACADEMY, UTOPIA CLUB, HISTORICAL SOCIETY OF PENNSYLVANIA and the COLLEGE of PHYSICIANS for the use of rooms.

To Dr. ISAAC LEA, PROVOST, TRUSTEES and FACULTY of the UNIVERSITY OF PENNSYLVANIA and the MANAGERS OF HAVERFORD COLLEGE, for the agreeable receptions which have afforded such delightful social opportunities to the members of the Association.

To the ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, together with the BOTANICAL, BIOLOGICAL and MICROSCOPICAL SECTIONS of the Academy for the many courtesies received.

To the ZOOLOGICAL GARDEN, and to the DIRECTORS and MANAGERS of the ELECTRICAL EXHIBITION for generous and valuable invitations.

To the COMMITTEE OF ARRANGEMENTS, AMERICAN MINING ENGINEERS, GIRARD COLLEGE, ATHENEUM OF PHILADELPHIA, NEW CENTURY CLUB, UNIVERSITY CLUB, U. S. MINT, DIRECTORS OF THE CITY TRUSTS OF PHILADELPHIA, GRAND MASTER OF THE FREE AND ACCEPTED MASONS, SONS OF ST. MARK, TRUSTEES AND FACULTY OF THE WOMAN'S MEDICAL COLLEGE, PENNSYLVANIA INST. OF THE DEAF AND DUMB, HOUSE OF REFUGE, PHILADELPHIA LIBRARY and the WAGNER FREE INST. OF SCIENCE, for the kind invitations extended to the members of the Association.

To the two YOUNG LADIES who have looked after the badges, and to the JANITOR of Horticultural Hall, for their faithfulness and courtesy.

To the ASSISTANT in the Association Post Office and to the TELEGRAPH OPERATOR, the RAIL ROAD OFFICIALS, and all others for the services they have rendered.

And last but not least, to the CITIZENS' RECEPTION COMMITTEE of Schuylkill County, for dinners at Mahogany Plane, on the Anthracite Excursion.

Professor HARKNESS of Washington, in seconding the resolution said:

The City of Philadelphia has certainly given the Association a warm reception [Laughter], but to do her justice she is not responsible for that. We have heard much before of Philadelphia hospitality — now we have experienced it. I can safely say that the words of the Governor who said that Pennsylvania bade us welcome have been made good, for have we not received courtesies from almost the entire State?

The reception promised us by Mayor Smith on behalf of the city has been fully lived up to. One great object of our annual meetings is the promotion of social intercourse among our members. They get acquainted with each other by means of receptions and reunions of the sort that have been tendered to us in profusion by the ladies and gentlemen of Philadelphia. We have had, too, at this meeting an element that never existed before. I refer to the presence of the members of the British Association. [Applause.] There have come among us from England, geologists, astronomers and biologists equal to any in the world, and some of them leaders in their particular branches.

Professor T. C. MENDENHALL, of Columbus, then made the following remarks: Our resolution of thanks, which is already so voluminous, might very well include the whole city directory. In fact, every one has helped us, from the telegraph companies down. If gratitude, by the way, consists of a lively appreciation of favors, those corporations ought to be satisfied. Members in appreciating their kind offices, have literally deluged them with telegrams. The only complaint that I have heard against the railroads is that each man did not have a special car.

After further remarks by Professors THURSTON and CLARKE, the resolutions were carried by acclamation.

President LESLEY announced that some of the British members had a few words to say. Captain BEDFORD PIM, R. N., then came forward and offered the following resolution:

That the members of the British Association, now present, tender to the citizens of Philadelphia, and especially to those ladies and gentlemen whose unwearied exertions have rendered this meeting such a memorable one, their most cordial thanks, with the assurance that the great consideration and unbounded kindness received on every occasion has made an impression which can never be effaced.

It is impossible to put into six lines our feelings at your brotherly greeting. I was going to say that we have received every attention from the highest to the lowest, but I suppose I must not make use of such an expression in a country where there are no lowest. Anyhow, you have treated us grandly. There is not one of you who has not done something for us. The very car conductors were the essence of politeness when we lost our way, which, I assure you, was often enough.

I am not altogether a stranger here. Seventeen years ago I was wrecked on your coast, and I had the good fortune to rescue several American lives from the ship Santiago de Cuba. At that time I received the most kindly treatment from everyone, including the newspapers.

I certainly prefer Philadelphia to any city in the Union. I shall go away

with my heart brimful of love to her and her people. Right here I want to say that I have set my heart on the American Association meeting in London. I think we can give you a reception only second to the one you have given us. [Applause.] Whatever conclusions you may come to about our Lord Mayor and common councilmen, they will give you some excellent turtle. Come when you want to. Come in 1886 if you can,—but come.

Professor BALL, Astronomer Royal of Ireland, in speaking of the hospitality of this country, said that he had got invitations from Virginia, Denver and San Francisco, and other places which it would take him years to fill. He was astonished at the enterprise and bigness of the Union. I had'nt landed here more than twenty-four hours, when an enterprising editor telegraphed asking me to wire him my opinion of the country, as it might be interesting to his readers. In conclusion, this I'll say, if I were fifteen years younger I'd come here and be a Yankee myself.

His Excellency Don ARTURO DE MARCOARTU of Madrid, and the Rev. E. W. SYLE of Japan, made remarks expressive of their gratitude, and the pleasures and importance of the meeting.

Remarks were also made by Prof. D. KIKUCHI, Dean of the Department of Science in the University of Tokio, who prophesied the establishment of an association for the advancement of science in his country.

Permanent Secretary PUTNAM, read a report giving the following statistics of the meeting:

The register shows the following attendance at the meeting: From England, 228; Scotland, 24; Ireland, 21; Canada, 19; New Brunswick, 8; Nova Scotia, 2; British Burmah, 1; making 303 from Great Britain; Japan, 4; Germany, 2; Russia, 1; Spain, 1; Panama, 1; making 312 from foreign countries. Pennsylvania, 238; New York, 161; Massachusetts, 87; District of Columbia, 84; New Jersey, 58; Ohio, 57; Connecticut, 32; Virginia, 22; Missouri, 20; Iowa, 19; Illinois, 18; Indiana, 17; Maryland, 17; Michigan, 10; Delaware, 9; Vermont, 9; Kentucky, 8; Tennessee, 8; New Hampshire, 7; Rhode Island, 6; Wisconsin, 6; Minnesota, 6; Texas, 6; Maine, 5; Florida, 5; Mississippi, 5; Kansas, 5; Georgia, 4; Alabama, 4; Louisiana, 4; Nebraska, 3; Colorado, 2; South Carolina, 2; West Virginia, 1; North Carolina, 1; Oregon, 1; California, 1; Wyoming Territory, 1; making 949 from the United States and a total of 1261. Five hundred and five new members were elected. Three hundred and five papers were presented as follows: Section A, 36; B, 42; C, 28; D, 18; E, 49; F, 58; G, 13; H, 30; I, 31.

The attendance was 264 greater than ever before and the number of papers larger than at any preceding meeting. These facts, with the international character which has been given to the meeting by the presence of so many distinguished men from other lands, mark it as the most successful the Association has ever held.

President LESLEY then adjourned the meeting.

ALFRED SPRINGER,
*General Secretary.*

## REPORT OF THE PERMANENT SECRETARY.

AT the age of thirty-six years the Association returned to the place of its birth and held the most important and largest meeting since its organization.

In order to permit of an interchange of courtesies between the British Association at Montreal and that of the American Association at Philadelphia, the meeting was called at a later date than usual, beginning on Thursday, September 4, and closing on the following Thursday. Our own members were thus enabled to attend the Montreal meeting where they were cordially welcomed, and about three hundred members of the British Association were afterwards at Philadelphia as the honored guests of the American Association.

The members of the Royal Society of Canada and delegates from various European and Asiatic Societies were also present as the guests of the Association.

The international character which was thus given to the Philadelphia meeting has not only prepared the way for a permanent international scientific congress, but has been of lasting value in binding, by closer ties, the English-speaking people of two great countries. Plans are already maturing for holding a meeting of the American Association in London at an early date.

The great success of the Philadelphia meeting was so largely due to the coöperation of the efficient and earnest Local Committee that it can only be mentioned in words of the highest praise. To its labors the members of the Association are deeply indebted, not only for their own cordial reception by state and city, but for the opportunity of receiving their honored guests and having them so well entertained.

In the preceding report of the General Secretary, notice has been taken of the many invitations to entertainments, receptions and excursions, which were accepted and enjoyed by all with such good will and fellowship, and I must refer to that report for a fuller appreciation of the general character of the meeting. The statistics of attendance are also given in the General Secretary's report and need not be recapitulated here except to state that twelve hundred and sixty-one names were registered.

Five hundred and five new members were elected: of these, four hundred and nine have accepted, one became an associate member, one has died, six have declined and eighty-eight have not yet replied to notices sent to them.

Thirty-nine members were made fellows: of these thirty have paid the enrolment fee.

Since the list of members was printed in the Minneapolis volume notice

has been received of the death of thirty-six members; thirty-three have resigned, and three hundred and two have been dropped from the list in consequence of arrearages, making a total of three hundred and seventy-one names taken from the list. The list in the present volume is augmented by four hundred names of new members elected at Philadelphia and of twenty old members who have paid back assessments, making a total addition of four hundred and twenty, or an increase for the year of forty-nine members.*

The addresses of the President and of the nine Vice Presidents are printed in the present volume. Two illustrated lectures were delivered in the evening at the Academy of Music before large audiences of members and citizens. Several reports were presented in General Session, and three hundred and five papers were brought before the nine Sections, and appear in this volume, as follows: SECTION A, 2 in full, 14 by abstract, 20 by title; SECTION B, 4 in full, 18 by abstract, 20 by title; SECTION C, 6 in full, 9 by abstract, 13 by title; SECTION D, 4 in full, 14 by abstract; SECTION E, 2 in full, 26 by abstract, 21 by title; SECTION F, 7 in full, 39 by abstract, 12 by title; SECTION G, 12 by abstract, 1 by title; SECTION H, 13 by abstract, 17 by title; SECTION I, 3 in full, 18 by abstract, 10 by title.

The editor of the Proceedings has done all in his power to get the present volume through the press, as early as possible, but owing to a serious prostration following the labors at the meeting, and confinement by illness in the early part of the winter, much time was lost. It must, however, be realized by all, that he should receive more assistance, if the volume is to be issued at an early date, for now that nine sections are in force, and his duties have so greatly increased by the growth of the Association in every way, it is necessary that he should receive direct assistance from the other secretaries. To this end, he respectfully requests the consideration of a plan by which each Secretary shall receive a small compensation, and shall be required to prepare for the press the papers which come under his charge. If each Secretary of a section would thus give over to the editor all papers, abstracts and titles ready for the press, an almost endless amount of letter writing and months of time would be saved.

During the past year, Volume 27 (St. Louis) has been reprinted by the voluntary subscriptions to the reprint fund, and 500 copies have been received from the printer.

Two thousand and seven copies of the Minneapolis volume were printed from the stereotype plates. Of these, fourteen hundred and thirty have been distributed to members, twenty-one copies have been sold and two hundred and sixteen have been sent out as exchanges and by special order of the Standing Committee; leaving three hundred and forty copies on hand.

The statement of the receipts and expenses for the year covering the

*The footings are not correctly given at end of list of members. On p. lxvi for 1491 read 1520 and on p. lxxxii for 1961 read 2082.

Minneapolis meeting, and closing on August 1, 1884, a month previous to the Philadelphia meeting, is given in the cash account on the following pages.

The general funds of the Association are as follows:—

LIFE MEMBERSHIP FUND.

| | | |
|---|---|---|
| Aug. 1, 1884. | Principal and interest | $2,322 22 |
| " 1, 1885. | Interest | 116 11 |
| " 1, 1885. | Additional commutations | 250 00 |
| | | $2,688 33 |

GENERAL FUND.

| | | |
|---|---|---|
| Aug. 1, 1884. | Principal and interest, | $93 35 |
| " 1, 1885. | Interest. | 4 67 |
| | | $98 02 |

REPRINTING FUND.

| | | |
|---|---|---|
| Aug. 1, 1884. | Principal and interest | $1,488 31 |
| | Cost of reprinting 500 copies of Vol. 27. | 1,035 34 |
| Aug. 1, 1885. | Balance on hand, | $ 452 97 |

MRS. THOMPSON'S GIFT.

| | | |
|---|---|---|
| Aug. 1, 1884. | Cash | $1,000 00 |

Respectfully submitted to the Association.

F. W. PUTNAM, *Permanent Secretary.*

SALEM, MASS.,
August 12, 1885.

F. W. PUTNAM, PERMANENT SECRETARY,

Dr. THE AMERICAN ASSOCIATION FOR

1883–4

| | | |
|---|---|---|
| To Balance from last account | | $201 86 |
| Assessments previous to 32nd Meeting . . | $636 00 | |
| " for " Meeting . . | 2,532 00 | |
| " " 33rd Meeting . . | 1,131 00 | |
| | | 4,299 00 |
| Admission fees previous to 32nd Meeting . | 15 00 | |
| " " for 32nd Meeting . | 605 00 | |
| " " " 33rd Meeting . | 45 00 | |
| Fellowship fees . . . . . | 118 00 | |
| | | 783 00 |
| Publications sold and binding . . . . . | 112 05 | |
| Sundry receipts . . . . . | 3 50 | |
| | | 115 55 |
| Interest on general fund of 88.90 | | 4 45 |
| Life memberships . . . . . | 250 00 | |
| Interest on life membership fund of 1973.51 . | 98 68 | |
| | | 348 68 |
| Reprinting fund; gift of Mrs. Herman . . . | 150 00 | |
| Interest on reprint fund of 1255.52 . . . . | 62 79 | |
| | | 212 79 |
| Balance due to Permanent Secretary | | 1,222 49 |
| | | $7,187 82 |

SALEM, MASS., AUGUST 20, 1884.

I have examined the above account and find

IN ACCOUNT WITH

THE ADVANCEMENT OF SCIENCE. Cr.

1883–4.

| | | |
|---|---|---|
| By 2000 copies Proceedings, Vol. 32, | | |
| Composition, stereotyping and plate boxes | $1,236 61 | |
| Illustrations | 1 60 | |
| Paper and press-work | 985 20 | |
| Binding, 1930 copies in paper covers | 482 50 | |
| " 50 " " cloth " | 25 00 | |
| " 20 " " ½ morocco | 20 00 | |
| 25 cloth covers extra | 5 00 | |
| Wrapping 2000 copies | 23 00 | |
| Extra copies of addresses and reports | 113 59 | |
| | | 2,892 50 |
| General expenses, Minneapolis Meeting | 485 94 | |
| 500 copies Constitution and list of Members | 71 86 | |
| | | 557 80 |
| Special list of members and fellows | 42 66 | |
| Circulars, blanks, cards, etc., | 234 00 | |
| Publications bought, and binding | 64 25 | |
| Binding books in library | 25 40 | |
| Postage and stationery | 318 20 | |
| Telegraph and telephone | 6 03 | |
| Express (including distribution of vols. 31, 32) | 648 29 | |
| Boxes for publications and packing | 16 71 | |
| Subscription to Postal Guide | 1 50 | |
| Post Office box | 8 00 | |
| Record books | 6 00 | |
| | | 1,371 04 |
| Rent of office | 100 00 | |
| Fuel | 19 00 | |
| Janitor | 56 00 | |
| Office expenses | 5 80 | |
| Extra labor and clerk hire | 48 06 | |
| | | 228 86 |
| General expenses, Philadelphia meeting | | 72 20 |
| Salary of Permanent Secretary | 1000 00 | |
| " " Assistant " | 500 00 | |
| | | 1,500 00 |
| Carried to general fund | 4 45 | |
| " " life membership fund | 348 68 | |
| " " reprint fund | 212 79 | |
| | | 565 92 |
| | | $7,187 82 |

the same correctly cast and properly vouched.

HENRY WHEATLAND, *Auditor.*

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